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ABSTRACT

This monograph presents a collection of papers that focus on excellence in teacher education and examine questions which are critical to the reform of curriculum and pedagogy. The 10 chapters are: (1) "Using a Multi-Dimensional Web Site for Physics Instruction" (James P. Downing and Ruwang Sung); (2) "College Algebra Reform: Documenting Student Attitudes and Performance" (Kelly Chappell and Darel Hardy); (3) "A Method for Increasing Scientific Literacy in Non-Majors Science Courses" (Karen Wardle); (4) "Math and Science Education Reform: A Community College Perspective" (Susan Hobson-Panico, Bill Hoard, and Chris Romero); (5) "Investigating the Role of Standards-Based Education in a Pre-Service Secondary Math Methods Course" (Lawrence M. Lesser); (6) "Meeting the Challenges of Diversity in a Context of Reform" (Nancy Hartley, Marta Cruz-Janzen, Kevin Oltjenbruns, and Jeff Farmer); (7) "Lecture? Group Work? Activities and Case Studies? A Search for Balance" (Roberta Smilnak, Steve Williams, and Betsy Forrest); (8) "The Genesis of Change: Teacher Preparation to Promote Implementation of Multicultural Math" (JoLean Ruggles, Marilyn J. Taylor, and Jeff Buck); (9) "Teaching Physics in an Experiential Learning Studio Environment" (Sanford Kern); and (10) "Chemistry Reform Takes Root in University Setting" (Thomas C. Pentecost). (Each chapter contains references.) (SM)

Promoting Excellence in Teacher Preparation:

Undergraduate Reforms in Mathematics and Science

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Edited by Myra L. Powers and Nancy K. Hartley

Colorado State University

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RMTEC

Rocky Mountain Teacher Education Collaborative
1999

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RMTEC

Rocky Mountain Teacher Education

The Rocky Mountain Teacher Education Collaborative (RMTEC) is an undergraduate education reform initiative funded by the National Science Foundation (NSF), under a program designated as a Collaborative for Excellence in Teacher Preparation (CETP). It is intended to support improvements in pre-service teacher preparation, and undergraduate teaching and learning, in mathematics and science. Six institutions of higher education are involved in the collaborative: Colorado State University, Metropolitan State College of Denver, University of Northern Colorado, (designated as the primary institutions); Aims Community College, Community College of Denver, and Front Range Community College. In addition, the Collaborative works with a number of other educational entities.

RMTEC goals are:

- To develop collaboration between the primary institutions, community colleges and local school districts.
- To improve the ways in which mathematics and science pre-service teachers are prepared for careers in teaching, with emphasis on restructuring, reforming and/or developing innovative curricula and instructional methods for teaching education, mathematics and science.
- To recruit and retain those sensitive to issues of women and ethnic minorities into teaching careers in the fields of mathematics and science.

From the time NSF awarded funding to RMTEC in 1994, the six participating colleges and universities have revised courses, raised diversity awareness, conducted research, and produced evaluative information that has been disseminated through workshops, professional products, websites and other professional connections. They have trained new teachers, made curriculum more interactive, provided scholarships, and developed a Teachers-in-Residence program.

Students indicate through surveys that the classroom environment of CTEP-trained teachers allows students a voice, makes learning less difficult, presents clear goals and objectives, and encourages experimentation. Preliminary evidence also suggests that RMTEC efforts have had a positive effect on student achievement, have improved attitudes and habits of mind, and have enhanced skills in science and math.

Foreword

The Rocky Mountain Teacher Education Collaborative (RMTEC), funded by the National Science Foundation, represents the efforts of faculty and staff of three state institutions of higher education, three community colleges and local school districts. Colorado State University, Metropolitan State College of Denver, and the University of Northern Colorado, the three primary institutions, each established teams composed of individuals from all entities involved, which served under the direction of the principal investigators on their respective campuses. Teams met individually, as part of a cluster of teams from their parent institutions as well as collaborative-wide, to initiate reform efforts and fulfill RMTEC goals. Reform efforts focused on student-centered, experiential, inquiry-based curricula and instruction, developed with sensitivity to the educational needs of women and students of color.

Capitalizing on the collaborative efforts of faculty from across institutions, teams of professors met to discuss reform efforts, methodology, and instructional strategies within disciplines across campuses. Initially, professors were offered stipends or instructional awards to their departments if they agreed to undertake course reforms that followed the RMTEC philosophy of student-centered, experiential, inquiry-based classrooms. As reforms were implemented, professors were encouraged to share their accomplishments, concerns, and issues with one another within collegial team settings. Support was provided by teams as well as by principal investigators on individual campuses. Some funding also was granted for disseminating results, presenting at conferences and developing products.

This project supported not only individual faculty efforts to reform courses but also the larger goal of institutionalizing the reforms. The impact of these efforts can be seen in the shift from a teacher-centered instructional paradigm to a student-centered learning paradigm. Illustrative of this shift are changes in emphasis from lecture to action-oriented learning outcomes; from knowledge of instructor to knowledge of student; from inputs to outcomes; from access for diverse students to success of diverse students; and from teacher-centered learning to student-centered learning.

Faculties were asked to consider the following questions as they embarked upon reform efforts within their areas:

1. Does the course engage students in inquiry-based, hand-on activities and field experience?
2. Does the course emphasize classroom-teaching strategies, such as cooperative learning, that are successful with women and students of color?
3. Is the course consistent with existing and emerging national standards for curriculum, teaching, and assessment of mathematics and science?
4. Is the course learning centered, does it allow students to take responsibility for their own learning?
5. Does the instructor demonstrate a variety of approaches to teaching and learning?
6. Does the instructor use technology to support learning?
7. Does the course integrate the understanding of mathematics, science, and education?
8. Does the course involve a cohort or community of learners?
9. Does the course effectively incorporate the knowledge and skills of experienced teachers?
10. Does the course have teacher, peer, and self-assessment embedded throughout?
11. Does the course build on research that demonstrates best practice?
12. Does the course involve reading, writing, and communication skills to develop student learning?
13. Are there varied ways a student can demonstrate attainment of the learning goals?

Each chapter of the monograph addresses some of these questions, which are critical to the reform of curriculum and pedagogy. The ten chapters cover the following content:

- **James Downing and Ruwang Sung** begin with a case study exploring use of the Internet's full potential in physics education to meet student needs.
- **Kelly Chappell and Darel Hardy** discuss new instructional approaches to college algebra that challenge students to explore the "why" behind mathematical ideas.
- **Karen Wardle** addresses new teaching strategies, making learning about science relevant to students' lives by examining similar patterns between science and their experiences in life.
- **Susan Hobson-Panico, Bill Hoard and Chris Romero** provide a community college perspective on encouraging science faculty to consider constructivist teaching and adopt small-scale science.
- **Lawrence Lesser** describes the incorporation of standards-based education in a pre-service secondary math methods course, and modeling teaching in a standards-based environment.
- **Nancy Hartley, Marta Cruz-Janzen, Kevin Oltjenbruns and Jeff Farmer** examine strategies related to the RMTEC goal of recruiting and retaining those sensitive to issues of women and ethnic minorities into teaching careers in mathematics and science.
- **Roberta Smilnak, Steve Williams and Betsy Forrest** explain revisions and evaluations of a geography course, incorporating case studies, simulations and passive research projects as strategies to promote active learning and student involvement.
- **JoLean Ruggles, Marilyn Taylor and Jeff Buck** review reforms that support math teacher candidates in their development and implementation of multicultural math lessons and equitable teaching practices.
- **Sanford Kern** describes the restructuring of introductory physics courses to model integrated lecture-laboratory approaches based on

understanding material and problem solving, versus traditional methods of rote memorization and application.

■ **Thomas Pentacost** discusses reforms to methods used in chemistry classes, including the incorporation of cooperative learning and guided inquiry experiences, and the use of guided readings.

To be sure, there are still many unresolved issues in this educational arena, however, participating entities have made major progress toward creating effective learning environments for students studying to be mathematics and science teachers at their institutions. This monograph was created to describe, through the use of case study, some reforms in courses that represent the major foci of the project: chemistry, earth resources, physics, mathematics, biology and education.

Appreciation is extended to the many professional colleagues involved in the RMTEC project, and to the National Science Foundation for funding our efforts to improve the undergraduate experience for students preparing to be mathematics and science teachers. We will not change our public schools if we do not change how we prepare teachers – and higher education must take a leadership role in this reform effort. The conscious and collaborative endeavors of schools and colleges of education, and arts and science faculty, are critical to enhancing the preparation of future teachers.

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1 Using A Multi-Dimensional Web Site for Physics Instruction

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With the advent of the microcomputer a little over a decade ago, we were debating the role of computers in the classroom, but now advances in technology are making it possible to debate the roles of the classroom in education.

—Blurton, 1994

The Internet, which barely existed in 1990, is now a tool used by millions of people daily. By 1996, one of seven households had access to the Internet (Rosen, 1996). By our actual survey, 45 percent of students at the University of Northern Colorado (UNC) now have Internet access at home, with the remaining 55 percent having access on campus. In early 1998, the UNC Physics Department installed its own server on the world wide web @ physics.unco.edu. Several physics professors at UNC now have created course web pages to provide schedules of exams, announcements, tutorials and other course business, as well as concept essays and lab instructions. The Internet is capable of assisting classroom instruction and enhancing certain aspects of it. However, a major question arises: Given the opportunity, will students voluntarily make full use of the Internet's capabilities, such as interactive chat rooms, bulletin boards, self-paced tutorials, and hot links to physics-related career pages?

Purpose of Study

Because the Internet is such a new resource, little research, especially in higher education, has been done to study its effects and guide its most effective pedagogical use, though expectations are running high. *With the advent of the microcomputer a little over a decade ago, we were debating the role of computers in the classroom, but now advances in technology are making it possible to debate the roles of the classroom in education* (Blurton, 1994).

Several UNC professors, whose students currently use course web pages, have been discussing the Internet's full potential in physics education, and want to find out more about how individual student needs could be addressed using the Internet's primary capabilities: e-mail, telenet and file transfer.

Students on the UNC campus already use the Internet to pay fees, select courses, and consult campus calendars. Students in five classes in the Physics Department have access to simple home pages for their course. Currently, the Internet is used as an electronic filing cabinet for remote access to hand-out material, and for access to an electronic syllabus and lab manual. Other possible functions of the Internet, not currently used by the UNC Physics Department, include: remote access to existing simulations of lab experiments; refresher tutorials and generic sample problems; interactive help sessions; a bulletin board to organize study groups; "How to" essays on various learning strategies such as "How to prepare for exams"; lists of supplementary materials of interest to curious students, e.g. links to NASA websites, newsgroups, listservs, books, videos, CD-ROMs and other material found in UNC's Michener Library; career guidance information; a guide to unsolved research in the field or potential student projects; self-tests; and physics curios and humor.

Method of Study

In order to examine which, if any, of these Internet pedagogical resources students might use and believe to be of help to them, Dr. Sung and Mr. Downing compared pre- and post-opinion surveys for student use of a multi-dimensional web-site, that is a site containing all three major functions of the Internet, i.e., e-mail, telenet and file transfer.

Major Issues and Other Questions Raised

Some Current Uses of the Internet in Higher Education

Computer Assisted Instruction of the 1980s and CD-ROM Interactive Instruction of the 1990s are new ways to deliver traditional content (Trowbridge & Bybee, 1996). But electronic mail via Internet adds an entirely new dimension to instruction: allowing interactive communication and collaboration with other people anywhere on Earth. The file transfer dimension of the Internet is not new in kind, but it is new in scope and scale. Potentially, the scale of data available on the Internet as compared to a single CD-ROM would be the difference between the Library of Congress, including picture, video and audio archives, and a single book. Project Gutenburg, http://www.promo.net/pg/ for example, makes electronic texts (e-texts)—documents in the public domain, from the Federalists Papers to Shakespeare's sonnets, loaded into computer files accessible from remote sites—available free to anyone. By 1994, nine billion e-texts had been posted electronically, and Project Gutenburg's goal is that by January 2002 one trillion e-texts and documents will be posted on line (Blurton, 1994).

Because of its multi-dimensional capability, *The Internet has become the most popular and widely available medium for distance learning and its popularity is increasing rapidly* (Price, 1996). At Texas Tech University, 40,000 enrollments in cyber courses were recorded in 1996 . This number exceeds on-campus enrollment. Purdue University has developed interactive on-line writing classes (Richardson, 1995).

The National Center for Atmospheric Research (NCAR) in Boulder has developed sets of computer-based training modules in atmospheric physics called COMET (for example, *Mesoscale Convective Systems: Squall Lines and Bow Echoes*), found on the Internet at http://www.comet.ucar.edu/ , which are qualitatively different from any print material. These computer based workshops contain hundreds of links to NCAR's gigantic picture, map and video archives and are updated regularly. The workshops' hypertext format can integrate onto one page of text, for example, the sound of tornado, video clips of recent tornadoes, even today's weather map and animated graphics.

At UNC, students enrolled in *SCI 106: Introduction to Spaceflight* and *SCI 109: The Cosmos* use a website called *The Solar System Collaboratory*, http://solarsystem.colorado.edu/, a joint project of UNC and three other Colorado universities. This site contains links to other websites related to space science as well as to interactive applets that allow students to investigate Kepler's Laws.

Healthy Skepticism About New Technology

For every potential to do good, a potential exists to do harm. Some use of the Internet in education seems to be motivated by wanting to be first with a new technology, or by a desire to project an up-to-date image. In 1996, Texas Tech University launched a new course titled *Introduction to Online Communications and the Internet.* Though popular with students in remote sites, the course was the electronic equivalent of a correspondence course, and the professor found that . . .*it is difficult to judge whether instructions and assignments are clear and whether course content meets student needs* (Price, 1996). A common student complaint was lack of interaction with a professor or other students. Some concerns about the proposed physics website at UNC have been expressed, and any additional use of computers needs to be consistent with our central purpose. The UNC Physics Department does not want a website that would:

- become a telecourse — a diluted, impersonal substitute for face-to-face physics;
- become a distraction or drag on student study time, which is already at a premium;

- undermine the cohesive effect and central role of the course instructor;
- increase the work load of professors, for example, by having to develop and monitor help-lines.

We are trying to avoid being dazzled by impressive new technology and losing sight of the basic principles of education. John Dewey, America's most famous philosopher and educational theorist, believed that education is a particular form of experience, and yet, *Education cannot be equated with experience because some experiences are mis-educative* (Dewey, 1938). According to Dewey, mis-educative experiences include activities that support careless or superficial thinking; offer knowledge in isolation, cut off from students' real world experiences; or require no student initiative, choice or planning.

Quality experiences, on the other hand, lead to future growth. Dewey says that such experiences include activities, assignments and assessments that:

- propel the student into future experiences of a richer, deeper nature and broaden the student's world;
- are agreeable to do;
- originate in the student's own needs and desires;
- build on the student's past experiences;
- start in the familiar world of everyday things and move progressively into the abstract;
- have community or societal tie-ins;
- prompt inquiry;
- strengthen initiative;
- set up desires strong enough to carry students over dead spots.

Our goal then, was to try to find ways to incorporate this powerful new tool, the Internet, into our instructional program without losing track of our fundamental task, which is to stimulate student achievement and growth in a supportive, humane environment. We constructed a physics website and later obtained feedback from students as to how much they used the website. Our chief questions were: 1) *Would students in science classes voluntarily customize their education along the lines of searching out materials to answer self-generated questions?* 2) *If students used a website, in what ways would they use it?*

Experimental Design

1. Students were divided into two groups: three classes (199 students) had a minimal web site available; two other classes (150 students) had a multi-dimensional website available. Students in all five classes were surveyed before the study began in order to get baseline data relating to how often and for how much time students access available web pages for their course.

Table 1: Classes Now Using Web Pages on the Internet

Course	Description	Fall 98 Enrollment	Comment
ENST 225	A multi-disciplinary general science course	50	Minimal web page offered
SCI 103	A general education science class	54	Minimal web page offered
SCI 265	Physical Science for Elementary Teachers	95	Minimal web page offered
PHY 220/221	Physics for non majors	90	Multi-dimensional website will be available
PHY 240/241	Physics for majors and future scientists	60	Multi-dimensional website will be available

Table 2: Results of Pre-Study Survey

(numbers indicate percent of surveyed students responding in each category)

#5 Access to a computer

		Only on campus	Share at home	Exclusive use at home
ENST 225	(N= 18)	28	39	28
SCI 103	(N= 45)	29	24	45
SCI 265	(N= 46)	20	44	37
PHYS 220	(N= 57)	44	26	30
PHYS 240	(N= 40)	25	33	43
Total physics	(N= 97)	36	29	35
All students	(N =211)	30	33	37

#6 Access to Internet

		Only on campus	Share at home	Exclusive use at home
ENST 225	(N= 18)	67	17	17
SCI 103	(N= 45)	51	16	31
SCI 265	(N= 46)	57	20	24
PHYS 220	(N= 57)	61	25	14
PHYS 240	(N= 40)	45	23	23
Total physics	(N= 97)	55	24	22
All students	(N =211)	54	21	24

#11 How likely are you to use the physics Chat Room?

		Definitely would not	Probably would not	Don't know	Probably would	Definitely would
ENST 225	(N= 18)	17	28	17	33	6
SCI 103	(N= 45)	16	20	33	24	7
SCI 265	(N= 46)	18	35	28	15	4
PHYS 220	(N= 57)	16	18	37	28	2
PHYS 240	(N= 40)	8	25	40	18	10
Total physics	(N= 97)	12	21	38	24	5
All students	(N =211)	14	25	33	22	5

#12 How likely are you to use the physics Bulletin Board?

		Definitely would not	Probably would not	Don't know	Probably would	Definitely would
ENST 225	(N= 18)	6	11	17	56	11
SCI 103	(N= 45)	4	11	13	58	13
SCI 265	(N= 46)	4	15	35	37	9
PHYS 220	(N= 57)	4	9	32	49	7
PHYS 240	(N= 40)	5	13	3	38	20
Total physics	(N= 97)	4	10	29	44	13
All students	(N =211)	4	11	26	47	11

Highlights of Pre-Study Survey:

- 70 percent of UNC students surveyed have access to a computer at home
- 45 percent have access to Internet at home
- 29 percent believed they would use a course chat room
- 58 percent believed they would use a course bulletin board

2. Using software purchased with the mini-grant funds, Dr. Sung created a multi-page physics site with:

- several pages of physics reference material including physics formulas and physical constants;
- a web bulletin board for undergraduates to post their questions and have more advanced students answer them anonymously;
- a physics chat room for students to talk directly with other physics students.

(To view the web page, see http://physics.unco.edu/isc/.)

3. At the end of the study period, the chat room and bulletin board results were tabulated. When we realized how little the site had been used, we changed our focus question from, *How did you use the web site?* to, *Why did students use the web site so seldom?* Students in three classes were re-surveyed and encouraged to write down their explanations for why students did not use the website.

Table 3: Results of Follow-up Survey: What Were the Main Reasons for Such Low Usage

#6 Of reference pages?

Course	Already had data	No access to computer	Didn't know	Didn't even know of site	Other reasons
SCI 265	26	9	14	49	1
(N= 82)	32%	11%	17%	60%	1%
PHYS 221	26	11	17	29	4
(N= 54)	48%	20%	31%	54%	24%
PHYS 241	18	11	13	8	9
(N= 38)	47%	29%	34%	21%	24%
Total physics	42	22	30	37	13
(N= 92)	46%	24%	33%	40%	14%

#7 Of remote tutor via bulletin board?

Course	Already had help	No access to computer	Didn't know address	Didn't even know of on-line tutoring	Other reasons
SCI 265	26	7	13	55	0
	32%	8%	1%	65%	0%
PHYS 221	25	10	17	32	3
	46%	19%	31%	59%	6%
PHYS 241	16	10	11	10	10
	42%	26%	29%	26%	26%
Total physics	41	20	28	42	13
	45%	33%	43%	46%	14%

#8 Of student chat room?

Course	Already had help	No access to computer	Didn't know address	Didn't even know of on-line tutoring	Other reasons
SCI 265	21	6	11	59	0
	29%	11%	13%	69%	0%
PHYS 221	34	10	16	31	3
	63%	19%	30%	54%	6%
PHYS 241	15	8	9	8	8
	39%	21%	24%	21%	21%
Total physics	49	18	22	39	11
	53%	20%	34%	42%	12%

Highlights of Responses to Post-Study Survey by Physics 221 and Physics 241 students:

to question #6 for not using **Reference Materials**

- 46 percent *Already had access to all data and formulas I needed*
- 40 percent *Didn't know there was a physics website with this information*

to question #7 for not using remote tutoring via **Bulletin Board**

- 46 percent *Didn't know there was a physics website with this service*
- 45 percent *Already had other means to get my questions answered*
- 43 percent *Didn't know the website address*

to question #8 for not using **Student Chat Room**

- 53 percent *Already had other means to get my questions answered*
- 42 percent *Didn't know there was a physics website with this service*

Expected Results Compared With Actual Results

We expected use of the Internet by students in Physics 221 and 241 to rise dramatically at first, due to students sampling the physics website. We further believed that two weeks after introduction of the website, use by the groups studied would either return to pre-study levels, if students did not use the website; or increase, if students did use the website, rising sharply (at least doubling) the pre-study usage.

Though 29 percent of the students predicted they would use the chat room, only a few percent actually did. Similarly, 57 percent of the students predicted they would use the bulletin board, but only a few percent actually did. It is clear from both the multiple choice survey and the open response questions, that the three main reasons for not using the web site were: 1) having other sources of help which were preferred to the web site; 2) not knowing about the site (or the site's address); and 3) not knowing generally how to use Bulletin Boards or Chat rooms, or not liking the impersonal nature of electronic communications.

Concluding Remarks and Recommendations for Further Study

Summary

The Internet's meteoric expansion since 1990 has prompted many people to search for ways to apply it; this is especially true for educators. Some Internet features have been highly successful in UNC science classes, for example, remote access to class syllabi, calendars, and handouts, especially lab instructions. In conducting this survey, we hoped to identify some indicators of the benefits and drawbacks of extensive use of the Internet.

At present, the Internet uses for reference materials, student-to-student talk via chat rooms and help sessions on line do not look promising for use in physics at UNC because these on-line services are duplicative of existing services that are more valued by the students. Reference materials are already contained in textbooks. Tutoring by course professors and advanced undergraduate students is already available. Students seeking help will find these means of assistance either more helpful or more personal than on-line help. It seems apparent that students will not use the Internet merely because it is a marvelous technological tool, but will tap it only when they can achieve some immediate aim. For students to use the Internet, professors must use it in a non-redundant way, integrating the Internet into the course framework by requiring assignments and course business to be conducted via the Internet. For example, student assignments could include Internet-specific assignments such as creating Webliographies (bibliographies of web sites); working in interactive student study groups; e-mailing the professor or others; viewing animations or experiment simulations using JAVA applets; retrieving remote data (e.g., from polar weather sites or ocean buoys); accessing private or government archives; downloading software, data files or graphics; and finding up-to-the-minute information in changing data bases.

Recommendations

- When incorporating a website as part of a course, the learning value and purpose of the site need to be clear and necessary, rather than being a marvelous add-on technology.
- Students need a better introduction to the site, and demonstration of the mechanics and usefulness of the site rather than just one mention that a site is available. The site should be linked with and accessible from existing university home pages.
- All physics classrooms should have a permanent posting of the website address in a highly visible place.

Questions for Further Investigation

- In what ways can the needs of education generally, and students in a specific course, be better served by use of the powerful features of Internet technology?
- What would a course that was using Internet technology to the fullest extent look like in practice?
- What do students need to know about the Internet to be fully technologically literate citizens and problem solvers?
- What kinds of assignments requiring use of the Internet are educationally sound, reasonable to ask of students, and fit within the existing constraints of class size, availability of computers, and professor's time for a given course?

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2 College Algebra Reform: Documenting Student Attitudes and Performance

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The course helped me to use the calculator, use scatter plots, graphs, and so forth to solve a problem in many ways. This approach will help me to understand and prepare for future math classes.

— Catriona

I kept resorting to what I knew worked and what I knew I could do. I tried the new ways [multiple approaches] but got frustrated.

— Tiare

— Comments from students taking *College Algebra in Context*

The first day of *College Algebra in Context* had arrived. Due to the design and philosophy of the course, I was finally going to teach as I believed mathematics should be taught.

In the past, I primarily lectured to my students, presenting mathematics as a collection of facts and procedures to be memorized. I simply felt trapped into this style of teaching. I was given a textbook and syllabus to follow. Both dictated that my job was to cover a wide range of procedures and algorithms. Due to the breadth of topics, I had to abandon depth.

Deep down, I suspected that my methods were not doing the subject of mathematics nor my students justice. Although I was successful in teaching my students to recall facts and perform memorized procedures and algorithms, a few questions haunted me. Although my students could manipulate symbols and equations and perform routine calculations, had they attached any conceptual meaning to the mathematics topics covered in the course? Could my students effectively communicate why these processes, formulas, and algorithms worked?

Unfortunately, I felt the answer to these questions would be no. However, instructional approaches that challenge students to explore the "why" behind mathematical ideas, and provide students with regular opportunities to read, write, and discuss them, would take considerable time to implement. I had to cover a wide range of topics and was pressed for time. I was hesitant to stray from the traditional approach because it allowed the coverage of a wide range of topics.

Perspectives of *College Algebra in Context*

I faced the challenge of teaching *College Algebra in Context*, a reform college algebra course that substitutes breadth with depth and represents a shift away from teaching students to recall facts and perform memorized procedures. The course covers a few topics carefully chosen on the bases of their perceived centrality to mathematics, but covers these topics in great depth. This streamlining of content paves the way for other ideals to be met.

The content, perspectives, and instructional strategies of *College Algebra in Context* reflect current reform in mathematics as articulated by the National Council of Teachers of Mathematics and the Mathematical Association of America. These organizations argue that many students learn and retain mathematics best in an environment in which students are actively involved in the learning process, oral and written communication of mathematical ideas is emphasized, and technology is used to develop and reinforce concepts. The *College Algebra in Context* environment makes minimal use of instructor-centered activities, such as lectures, and maximum use of student-centered activities that invite students to actively construct knowledge, uncover meaning behind mathematical concepts, and communicate mathematical ideas.

The three central goals of the course are as follows:

- To prepare students to understand and explain why they apply certain mathematical concepts and techniques to solve problems.
- To prepare students to employ multiple strategies as they engage in problem solving.

- To prepare students to communicate their mathematical understanding effectively.

I was excited by these goals, believed in them, and was prepared to meet this new instructional challenge.

Describing *College Algebra in Context*: A Classroom Scenario

From the first day of class, students were the primary focus of my classroom. They were actively involved in the learning process, actively constructing knowledge, and communicating mathematical ideas. Oral and written communication of mathematical ideas was emphasized and technology was used to reinforce concepts.

I was genuinely interested in students' reasoning, as they explained why they applied certain mathematical concepts and techniques to solve problems. The correct answer was valued only if the students could explain why it made sense to work the problem as they did. Processes that led to incorrect answers were used as instructional tools to enhance learning. The class would consider the process that led to the incorrect answer, discuss why the process did not work, and then modify the process.

Students presented to the class the multiple strategies employed as they engaged in problem solving. I often stressed the importance of being able to work a problem in more than one way. Many classroom activities began with qualitative descriptions of mathematical relationships, progressed through data collection that reinforced the qualitative data, and concluded with algebraic and graphical descriptions. As a result, students developed fluency in representing mathematical situations in a variety of ways: numerically, graphically, and algebraically. Classroom activities required students to reason, make predictions, test the predictions, and then modify the predictions in order to construct knowledge. Students attached meaning to concepts they merely had memorized in the past.

I respected and built instruction around students' misconceptions, ideas, and insights. I did not try to structure the students' thinking in order to lead them to the correct answer. Instead, I focused on creating an atmosphere that provided opportunities for students to structure their own thinking. I gave students the time they needed to investigate and develop solutions. I no longer asked students only for their answers. I asked also for the strategy they used to arrive at the answers and how they thought about it. I valued their methods.

Technology was used to enhance conceptual understanding. For instance, graphing calculators were used to underscore the interconnection between algebraic and graphical approaches. Students used the graphing calculators to construct patterns and then explored these patterns to discover mathematical concepts.

Student Attitudes: Differing Perspectives and Reactions to the Course

My excitement was tempered by an emerging concern. The majority of my students had learned mathematics by watching teachers demonstrate how to do a problem and then practicing solving problems of the same type. *College Algebra in Context* was a drastically different approach to mathematics than most of my students had encountered in the past, and they were reacting to the new approach in different ways. Two camps were beginning to form. Students in the first camp admitted that the new approaches to learning mathematics could be uncomfortable, but they seemed to value them because they were helping students to finally understand mathematics. Students in the second camp solely valued right answers and "the right method" for finding those answers. Using multiple approaches or being able to explain a method of solution were seen by these students as a complete waste of time. They believed that the teacher's job is to explain and the student's job is to regurgitate (quickly and accurately) processes the teacher had previously performed.

I wanted to gain insight into the differing perspectives and reactions to the course. I met with two students after class who I knew represented opposing viewpoints, and believed would openly and honestly share their perspectives. The reactions of the two "camps" are best analyzed through the discussion that ensued.

I told the students that one of the goals of *College Algebra in Context* is to prepare students to solve problems in more than one way. I asked Catriona and Tiare if they believed that the course had achieved this goal. Catriona responded first.

The course helped me to use the calculator, use scatter plots, graphs, and so forth to solve a problem in many ways. This approach will help me to understand and prepare for future math classes.

Tiare disagreed.

I kept resorting to what I knew worked and what I knew I could do. I tried the new ways (multiple approaches) but got frustrated.

Catriona and Tiare agreed that *College Algebra in Context* focused on multiple approaches to solving problems. They disagreed about whether or not such a focus was useful. Tiare clearly had the attitude that there should be "one right way" to work each problem, and the instructor's job should be to give students that one way.

There isn't enough time in class to learn several methods. Several methods to solve a problem confuse me. I find it easier to solve a problem using the method that is most accurate and easiest.

Catriona countered this argument.

Multiple approaches help me to understand the problems more in real life. It helps me realize just what is happening if I can do it in many different ways.

I explained that the intent of *College Algebra in Context* is to provide students with regular opportunities to read, write, and discuss mathematical ideas. I asked Catriona and Tiare if they benefited from this approach. Catriona felt that she did benefit.

After so many years of not understanding math at all, because it was just me memorizing crap in high school, I am finally learning by discussing, which is a better approach for me. In high school, the thinking was left up to the teacher or the textbook and my job was to regurgitate processes that the teacher had demonstrated. I am excited that I am finally understanding math.

Tiare could not hold back.

Math is math and doesn't need to be mixed with writing and discussion! I'm not the teacher, I'm the student. Why should I have to explain. I hate having to explain what I did when solving a problem. I know what I did! I have learned for twelve years to just solve the problem and not sit there and explain everything. Math is a very personal thing and it can be hard to explain to others one's own thought process.

I asked them to tell me more about how *College Algebra in Context* differs from their high school courses in mathematics. I asked which type class they preferred. Tiare responded first.

High school was straightforward question answering with no explanations and no recap involved for each question. I liked the high school approach more because I feel I learned more because I wasn't so worried about forgetting something. I just concentrated on the problem. I find College Algebra in Context a lot of nonsense that I don't really need. I've learned math by being given a formula and then using it and not explaining what I did and how I came to that conclusion. In the real world no one cares what thought processes you went through to come to the conclusion, they just want to know what the conclusion is.

Catriona agreed with Tiare about what the differences were, but certainly not on which approach was better.

This class explains "why" more than high school did, so I understand better. Now I'm actually learning the stuff rather than trying to memorize it. This approach requires more time, but it's worth it. In high school, we did not get as much depth with problems, especially on how or why something works. I remember thinking in high school, "When am I ever going to use this stuff?" Now, at least I can see how algebra is used in the real world.

I thanked Catriona and Tiare for their honesty and openness, and they were on their way. I had found two students who represented the divergent views and attitudes of the two camps. Although Tiare expressed a generally negative attitude, it was also clear from her comments that the course represented a distinct change from the past, and that many of the course goals had indeed been achieved.

The discussion suggests that students find the transition into a reform learning environment to be uncomfortable. Both of these students were products of twelve years of traditional mathematics education. Their comments indicated that they had never been required to "think" about mathematics until *College Algebra in Context.* In the past, thinking was left up to the teacher or textbook.

Assessing Student Achievement

With the course nearing an end, I was extremely proud of my students' accomplishments. The students rose to the challenge of engaging in conceptual thinking about mathematics. They achieved the goals of *College Algebra in Context,* and were able to think deeply about mathematics by discovering, conceptualizing, and applying mathematics to non-routine problems. Students approached problems with alternative methods and effectively communicated these methods and results. However, my sense of satisfaction was bittersweet in that I was once again haunted by an important question. Does the *College Algebra in Context* approach to teaching and learning prepare students for the mathematics courses they will encounter in the future?

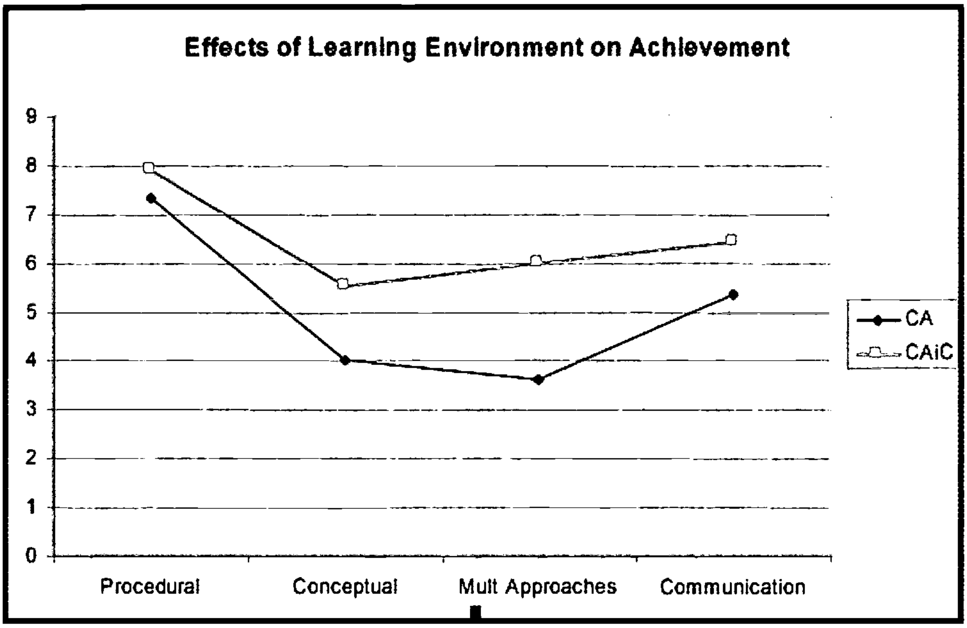
Reality dictates that many of my students will enter classes where symbol manipulation is valued over conceptual understanding. I worried that the *College Algebra in Context* approach may be detrimental to the students who pursued courses where manipulations are of paramount importance. I wanted to collect empirical evidence that would help address these issues.

A study was designed to investigate the impact of reform versus traditional learning environments on student achievement. A paper and pencil, three-item assessment was developed to measure students' ability to solve and explain problems involving linear relationships and the associated procedural skills. Each item consisted of multiple parts that assessed four dimensions of student achievement: procedural knowledge, conceptual understanding, ability to employ multiple approaches, and communication skills. To ensure fairness, the assessment was designed and reviewed by *College Algebra in Context* instructors as well as by instructors of the traditionally taught sections of college algebra. The scores on each dimension ranged from 0 to 9, with 0 indicating unscorable work and 9 indicating the student had achieved the knowledge or skills defined in the dimension. The scores on the assessment were assumed to be interval.

Fifty-one mathematics students (19 reform college algebra students and 32 traditionally taught algebra students) independently completed the assessment. Participants included both male and female students, traditional and non-traditional students, and students of varying mathematical abilities. Students could use graphing calculators while completing the assessment, but could not use any other resources, such as class notes or the textbook.

All student work was scored by two instructors who were blind to the learning environment of each student. The students' scores on the assessment were subjected to an independent group t-test to analyze the effects of reform versus traditional learning environments on students' procedural knowledge, conceptual understanding, ability to employ multiple approaches, and communication skills. The alpha level, to accommodate the four contrasts, was set at .025, which is the acceptable procedure for controlling experiment-wise error rate for multiple contrasts. Therefore, the alpha level to be considered for the demonstration of significance is alpha<.025. The mean scores of the reform students (CAIC), on each dimension, were higher than the mean scores of the traditionally taught students(CA) (see Table). Student work provides additional insights into the results.

Table


Effects of Learning Environment on Achievement
9
8
7
6
5
4
3
2
1
0
Procedural
Conceptual
Mult Approaches
Communication
CA
CAiC

Multiple Approaches

Results indicated that the *College Algebra in Context* students' scores on the multiple approach section of the assessment were significantly higher (alpha=.001) than the scores of the students enrolled in the traditional lecture-based algebra course. *College Algebra in Context* students were able to analyze problems through a variety of lenses and approach problems in a myriad of ways. The student work shown in Figure 1 illustrates the ability of the *College Algebra in Context* students to employ multiple approaches to reach a solution and is representative of the responses received from the *College Algebra in Context* students.

Figure 1

(d) Find the x-intercept of the line $2x + 3y = 5$ and explain how you found this number.

The x-intercept of the line 2x+3y=5 is 2.5. I found this number by entering the equation in the calculator in the slope intercept form of y=-2/3x+5/3. I then used the zoom function to find the most possible accurate answer which was 2.5.

(e) Describe a second method that you might use to find the x-intercept of the line $2x + 3y = 5$.

Another method that could be used would be to plug 0 in for y and solve the equation.

$$2x+3(0)=5$$
$$2x=5$$
$$x=5/2$$
$$x=2.5$$

This student's work on the assessment demonstrates the interconnection between algebraic and graphical approaches. The *College Algebra in Context* students were able to approach the problems numerically, graphically, and algebraically.

The students taught via a traditional approach to algebra tended to solve problems using the method that had been directly taught in the course, as illustrated by the following student's response (see Figure 2).

Figure 2

(d) Find the x-intercept of the line $2x + 3y = 5$ and explain how you found this number.

$2x + 3(0) = 5$
$2x + 0 = 5$
$\frac{2x}{2} = \frac{5}{2}$ $\quad x = 5/2$ $\quad$? $\quad$ *I forgot how to find x-int*

(e) Describe a second method that you might use to find the x-intercept of the line $2x + 3y = 5$.

The student was unable to present more than one solution and seemed unsure about the correct solution that was presented. The student's work did not show any evidence of having made the connection between the algebraic and geometric solutions.

Procedural Skills

Results suggest that the learning environment resulted in no significant differences (alpha =.228) in the students' abilities to employ procedural skills. Upon closer inspection of the student work, it became evident that the two classes approached procedural problems somewhat differently. Students in the traditionally taught college algebra course manipulated equations more efficiently and used fewer steps to arrive at their answers (see Figure 3) than students in *College Algebra in Context* (see Figure 4). The longer solution could be a conscious effort on the part of the student in *College Algebra in Context* to justify the steps.

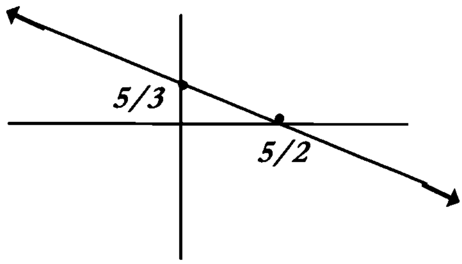
Figure 3

(a) Rewrite the equation $2x + 3y = 5$ in the form $y = mx + b$.

$$3y = -2x + 5$$

$$y = \frac{-2}{3}x + \frac{5}{3}$$

(b) Sketch a graph of the line $2x + 3y = 5$.



X	Y
0	5/3
5/2	0

Figure 4

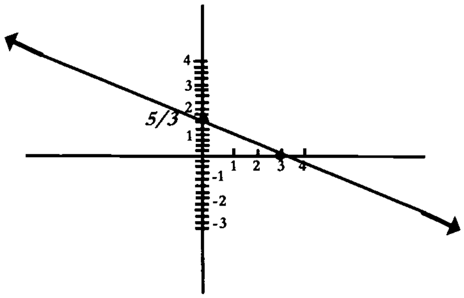
(a) Rewrite the equation $2x + 3y = 5$ in the form $y = mx + b$.

$$\cancel{2x} + 3y = 5 - 2x$$
$$\cancel{-2x}$$

$$\frac{\cancel{3}y}{\cancel{3}} = \frac{5-2x}{3}$$

$$y = \frac{-2x+5}{3} \quad \text{or} \quad y = -2/3x + 5/3$$

(b) Sketch a graph of the line $2x + 3y = 5$



Communication

Results indicated that the *College Algebra in Context* students' scores on the communication section of the assessment were significantly higher (alpha =.023) than the scores of the students enrolled in the traditional lecture-based algebra course. The majority of students in the traditionally taught section of college algebra were not willing, or possibly not able, to communicate mathematics in a way that an eighth grader could understand. These students, as Figures 5 and 6 reveal, most often answered the question with textbook descriptions of "*m*" and "*b*" such as slope, rise over run, and *y*-intercept.

Figure 5

(c) How would you explain to an eighth grader what the "*m*" means and what the "*b*" means?

m = slope
b = y - intercept

Figure 6

(c) How would you explain to an eighth grader what the "*m*" means and what the "*b*" means?

m = slope: $\frac{Rise}{Run}$

B = Y-Int; where the line crosses the Y-Axis

Furthermore, the *College Algebra in Context* students were better able to provide detailed solutions. For example, many of the *College Algebra in Context* students, as illustrated by the student's response in Figure 7, described clear methods for finding the *x*-intercept graphically.

Figure 7

(d) Find the x-intercept of the line $2x + 3y = 5$ and explain how you found this number.

$2x + 3y = 5$	*$y = 0$*
$2x + 3(0) = 5$	*$x = 5/2$*
$2x = 5$	*Substitute 0 for y and that gives you*
$x = 5/2$	*the value of x-intercept*

(e) Describe a second method that you might use to find the x-intercept of the line $2x + 3y = 5$.

Use the trace mode on your calculator in the graph mode and use the curser until y=0 and that gives you your x-intercept.

In contrast, the majority of students in the traditionally instructed section, as illustrated by the student's response in Figure 8, provided vague methods for finding the x-intercept graphically.

Figure 8

(d) Find the x-intercept of the line $2x + 3y = 5$ and explain how you found this number.

$$2x = -3y + 5$$
$$x = \frac{-3y}{2} + \frac{5}{2}$$

$\boxed{5/2}$ *I found this number by setting the equation equal to x and then finding the intercept.*

(e) Describe a second method that you might use to find the x-intercept of the line $2x + 3y = 5$.

Graph the line and see where it goes through the x-axis.

Conceptual Understanding

Results indicated that the *College Algebra in Context* students' scores on the conceptual section of the assessment were significantly higher (alpha

=.001) than the scores of the students enrolled in the traditional lecture-based algebra course. The *College Algebra in Context* students, as Figures 9 and 10 reveal, often used the same textbook terms but incorporated real-life analogies and concrete descriptions into their writing that would help communicate the conceptual meaning of terms.

Figure 9

(c) How would you explain to an eighth grader what the *"m"* means and what the *"b"* means?

The m is the slope of the line or the change in y divided by the change in x. For a slope of -2/3 plot a point, go down two units and to the right 3 and you have another point on the line.

The b is where the line intersects the y-axis at 5/3.

Figure 10

c) How would you explain to an eighth grader what the *"m"* means and what the *"b"* means?

I would say m is the steepness of the line and I would compare that to a ski hill or a mountain.

For B, I would tell them that b is where the line crosses the y-axis on an (x,y) coordinate plane.

Conclusion

In many ways, the results discussed in this case study are not surprising. The *College Algebra in Context* students were exposed to fewer mathematical topics and acquired fewer procedural skills than the traditionally taught students, but studied these topics and procedural skills in much more depth. The *College Algebra in Context* students were taught to employ multiple approaches to solve problems and communicate conceptual understanding effectively and, not surprisingly, they excelled in these areas. The traditionally taught students were introduced to considerably more mathematical topics and acquired more skills, but only studied these topics and skills on a procedural level. The traditionally taught students were not required to employ multiple approaches to solve problems, conceptualize mathematical ideas, nor communicate effectively, and they did not excel in these areas. However, they were exposed to more topics and acquired more skills on a procedural level.

Herein lies the dilemma. In order to focus on conceptual understanding, the coverage of some procedural skills must be sacrificed. In order to focus on procedural skills, some conceptual knowledge must be sacrificed.

Thus, the important question reduces to what we value. What "skills" are appropriate for the mathematics students of today? Based on my experiences, I assert that procedural skills will be quickly forgotten if a conceptual understanding is not achieved first. If students are to recall or reconstruct procedural skills, they must have some understanding of the meaning behind the skills. I strongly believe that the traditionally taught section of college algebra does nothing more than teach students to memorize and practice the same litany of routine procedures they most likely have been exposed to in high school. *College Algebra in Context* teaches students how to effectively analyze and think critically about mathematical situations with understanding, and then effectively communicate strategies and solutions. These higher-level "skills" transcend mathematics, and provide students with advantages in a range of situations. These students are learning to think critically about mathematics.

I urge collegiate mathematics communities to reconsider the set of skills they deem appropriate for the mathematics students of today. From my perspective and experience, depth of understanding should be the focus of college level mathematics courses, suggesting that procedural skills may be best replaced with higher-level skills such those espoused in *College Algebra in Context.*

3 A Method for Increasing Scientific Literacy in Non-Majors Science Courses

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. . .in addition to preparing students for science careers, the education system must . . .provide scientific and technical understanding so that citizens may make informed decisions as consumers and as citizens. To achieve these goals, schools must be able to develop curricula that are rigorous, develop critical thinking, and impart an appreciation of the excitement and utility of science.

—House Education Committee on Science,
1998 Report to Congress

Teaching biology to non-science majors can be a nightmare for instructors. They face a classroom of students who are simply taking the required science course to get it out of the way, and often have little interest in the subject material. Typically in community colleges, the non-science majors course is taught as a one semester, modified majors, general college biology course. The same number of concepts are introduced, but in less detail. My goal in the RMTEC study was to use a new approach to teaching non-science majors the required biology content.

Background

The typical intent of a non-science majors course is to increase scientific literacy among the general population, not to increase the number of students entering science careers. Naturally, an instructor needs to ask the question, *What are the characteristics of a scientifically literate person?* There are many definitions of scientific literacy, however the common understanding appears to be that the scientifically literate person is able to understand and make decisions about the scientific concepts pertinent to his or her individual and social well-being and the natural world (Feder, 1999), (Gingrich, 1998), (Hatton & Plouffe, 1997), (Hurd, 1998), (Rutherford & Ahlgren, 1990). The House Committee on Science stated in a 1998 report to Congress that in addition to preparing students for science careers, the education system must . . .*provide scientific and technical understanding so that citizens may make informed decisions as consumers and as citizens. To achieve these goals, schools must be able to develop curricula that are rigorous, develop critical thinking, and impart an appreciation of the excitement and utility of science* (House Committee on Science, 1998). The National Science Standards of 1996 are utilized as the goals for teaching science at the K-12 level (American Association for the Advancement of Science, 1993). The authors of these standards identified the concept of scientific literacy as . . .*the knowledge and understanding of scientific concepts and processes required for personal decision making, participating in civic and cultural affairs, and economic productivity* (American Association for the Advancement of Science, 1993).

To increase their scientific knowledge, students need to develop an interest in scientific issues. They need sufficient knowledge of scientific concepts to understand the purpose of public policies and practices aimed at increasing and maintaining the health and welfare of the Earth and all its inhabitants. Niles Eldredge (1999), in his book *Patterns in Evolution,* describes the relationship between our understanding of the world in which we live and the material world itself as one of matching patterns through models of how we believe the world operates. In order to create the models, we need to be students of nature and recognize the intricate patterns between our mental pictures of the world and the physical reality of the world. Eldredge states that, *Science is a way of seeing the material world, and pattern perception is at its core.* As an instructor, placing the emphasis on scientific literacy in the non-science majors' curriculum requires teaching students to recognize patterns between their lives and scientific concepts. This matching of patterns requires more that just a simple identification of a resemblance between a part of your life and a scientific phenomena; it requires an examination to be of any lasting value (Moriarity, 1997).

The goal of the new teaching strategy is to place the concepts outlined in the traditional course curriculum guide for the non-majors course into a framework that makes learning about science relevant to students' lives by examining similar patterns between science and their experiences in life; increases the amount of student participation in the exploration of matching patterns in science with that of their personal lives; and introduces critical thinking skills into the curriculum.

Purpose and Method of Study

Rather than focusing on having students strictly memorize biological concepts, for example, amino acid structure, the goal was to add to the curriculum an examination of how amino acids were related to students' diets and how their bodies utilized amino acids. To scrutinize patterns between relevant biology concepts such as amino acid structure and students' lives, critical thinking skills were introduced in the form of delving deeper into particular concepts and analyzing them using traditional problem solving methods. In addition to the recognition of patterns in the scientific world, the repetitive use of problem solving techniques will give students a tool they can use when faced with making decisions in their lives (Siegel, 1988). Critical thinking and problem solving are learned skills that enable us, as humans, to enjoy great success in understanding and manipulating our environment (Browne-Miller, 1994), (Ellis, 1997), (Kitahara, 1991), (Rochelle & Clancey, 1992), (Wilson, 1978). The method used to accomplish the goal involved adding a series of case studies with an overall theme to further analyze the patterns between science and real life experiences. Case studies were conducted at the close of lectures on the concepts relevant to the targeted in-depth study.

The central theme chosen was an examination of the planet Mars. A trip to Mars was not relevant to my students' lives, however, it was chosen due to its broad application to the concepts I wanted to target. I also needed a theme that provided students with availability and accessibility to the subject material. Mars exploration and the subsequent discoveries of the Mars Global Surveyor were in the news at the time I was planning curriculum changes, and therefore information was available to the majority of students. A series of four case studies, based on the central theme of Mars exploration, was added to the course. Concepts targeted for in-depth study included the scientific process, nutrition, natural selection and conservation. The use of case studies provides an environment in which to facilitate the learning of critical thinking skills. Establishing unique environments allows the instructor to set up a framework to introduce critical thinking skills, for example, participating in debates, solving problems, and evaluating evidence. Creating an environment for the case studies, that paralleled the ongoing research of the planet Mars, lent credibility to the cases.

Case studies are gaining in popularity as a tool to teach science. The *Journal of College Science Teaching* has its own Case Study Department that contributes a monthly article dedicated to case studies (Allen & Herreid, 1998), (Herreid, 1997), (Peaslee, Lantz, & Walczak, 1998). One of the cases examined the evidence for the existence of microbial on Mars (Allen & Herreid, 1998). Analysis of the case studies was grounded in a basic model for problem solving. The model involved identifying the problems or issues in the case; examining the evidence for the problems based on the facts of the case, not inferences; identifying solutions to the problems or issues; examining the positive and negative consequences of the solutions; and evaluating the success of the solution. The instructional design around the case studies involved student collaboration on the problem solving assignments, followed by large group discussions prior to completion of these assignments. Written assignments were added to traditional quizzes and exams and were based on the problem-solving model mentioned above.

The Issues

The scientific process can be described as a process designed to test patterns between what is hypothesized to be a pattern and the experimentation to identify if that pattern actually exists (Feder, 1999), (Giere, 1977). In the first case study, students addressed the question of whether or not life existed on Mars. They read two articles with the same hypothesis: life once existed on Mars. One article was from the magazine *Science News* and hypothesized that microbial life once existed on Mars (Cowen, 1996). The other article was from the Internet, and hypothesized that intelligent life once existed on Mars and left behind evidence in the form of monuments, for example the face on Mars (The Cydonia Files, 1997). Students examined the evidence for the hypotheses based on the scientific process. They then examined the evidence for life on Mars directed toward the general public in local newspapers. The initial critical thinking skill introduced in Case Study 1 was the use of evidence in evaluation of hypotheses and opinions. Since the dilemma of whether life exists or once existed on Mars is difficult to test from Earth, the second case study involved a trip to Mars. Zubrin (1996), in his book *The Case for Mars,* outlines in detail everything needed for initial trips to Mars to terraforming the planet. Based on his information, the class planned a trip to Mars.

The second concept I targeted revolved around the question: Why do we eat and breathe? Students examined this question by learning about the periodic table of elements, how these elements come together to form molecules, how macromolecules form the foods they consume and finally, how the food they consume is transformed into energy. The second case study focused on an initial trip to Mars. The class hypothetically traveled as part of the crew with the purpose of examining the biology and chemistry of Mars. The planet's environment was examined for the elements necessary to sustain life, and for the manufacture of fuel. The goal for the students was to find a solution to the packing of necessary food and fuel to travel to and from Mars, a two and a half-year journey. They kept in mind certain factors in their solution, for example nutrition, weight, preservation and psychological factors. Critical thinking skills that were added to Case Studies 2 through 4 were the formulation of solutions to problems and the analysis of those solutions.

The initial trip to Mars turned into colonization and eventually terraforming Mars. Students studied genetics and evolution by hypothesizing how their descendants might change due to the different environmental conditions on Mars. The concepts of natural selection and evolution are difficult subjects for students to fully understand, and we worked out a number of misconceptions about the subjects by discussing changes that might result if we were to colonize Mars and be isolated from the human population on Earth.

The final case examined the environment on Mars. The greenhouse effect was studied as a means of creating an atmosphere on Mars. Students then examined how the greenhouse effect causes problems on the Earth. Unfortunately, this particular case gets shortchanged due to a lack of time, and the fact that it needs to be a whole course unto itself.

Descriptive Details

The first case study focused on the scientific process as a tool to evaluate differing hypotheses for life on Mars. Students learned the method of communication and matching patterns by analyzing hypotheses and observations using scientific methodology. Throughout discussions conducted on the subject, students also were required to back up their opinions with evidence from papers. This initial skill of using evidence to back up their opinions set the stage for further development of critical thinking skills. Students enjoyed scrutinizing the articles, especially the one hypothesizing that the face on Mars was left by an intelligent civilization. Included in the scrutiny of the face on Mars was an examination of the face at all angles using the National Science Teachers Association CD-ROM – *Views of the Solar System* (NSTA, 1996). Based on evidence the students accumulated, they formed their own opinion as to the existence of life on Mars. The initial discussion was very one-sided; the students were from very diverse backgrounds, and it took time for them to realize the classroom was a relatively safe environment to express their opinions.

The second case was not presented until topics on energy were finished, about mid- semester. By this time, the students had worked together in labs and were more comfortable speaking in class. Additionally, Case Study 2 is a familiar subject to students so they joined in both small and large group discussions readily. By the time Case Study 2 was conducted, students were bringing in information they researched on their own. Mars was a regular feature in the news at the time due to the launching of the Global Surveyor, and material was accessible. One gauge of student interest was the amount of material brought in from outside sources and this case had the greatest amount of information contributed by the largest number of students. I enjoyed this case study because it integrated and examined ongoing issues in chemistry, biology and physics.

Analyzing the food and fuel needs for a trip to Mars involved a discussion of simple chemical reactions, for example $CO_2 + 4H_2$ — $CH_4 + 2\ H_2O$. At the time Case Study 2 was introduced, chemistry concepts were old news by approximately three weeks. Therefore, the case study was an opportunity to revisit important, yet forgotten, concepts and integrate chemistry concepts. A discussion of when to depart for Mars with respect to the orbits of both Mars and Earth created an opportunity to integrate conceptual physics into the case. A lively discussion followed when it was proposed to be easier to travel to Mars when Mars and Earth were on opposite sides of the sun. Students asked a significant number of questions about conceptual physics, which was a surprise considering the fear the word physics often holds for them. The discussions gave students confidence that they could understand some of the basic concepts used in rocket science.

Lively discussions continued into the third and fourth case studies. During the third case study on evolution, students began bringing in newspaper clippings on a variety of topics in evolution. Toward the end of the semester, the level of involvement and participation in learning the science concepts increased greatly. Increased interest in science topics enhanced the learning experience and turned lectures into discussions. Consequently, I was always behind with the material I needed to cover for the semester.

Assertions

The use of case studies to increase class discussions proved to be a good method to stimulate interest in the subject matter, and formed an enjoyable framework around which several interesting discussions evolved in class. Collaborative exercises were increased, as the students became comfortable with expressing and backing up their opinions in front of their peers. As the semester progressed, students increased their participation in the learning experience by sharing experiences from their lives. These findings are consistent with McDade (1995) and Welty (1989). Discussions became lively as the semester progressed, sometimes to the point where I had to review conflict management techniques. Initially, the idea of a trip to Mars sounded silly to the students, but once we began discussions on the science involved, they became increasingly interested in the material. It was not unusual for students to pick up books on Mars, and bring in survival kit material. One student brought me the press kit for the Mars Global Surveyor Arrival 1997 (Isbell & O'Donnell, 1997), and suggested a field trip to Lockheed Martin Astronautics. Since non-science majors are exposed to the material only once in their college studies, the focus on scientific literacy and the students' participation in the material enabled me to feel good about the knowledge the students would take with them after the semester.

Problems encountered involved balancing the emphasis on learning the required content material for traditional exams, and the case studies. The first semester I utilized the case studies, students' grades on traditional exams to test basic concepts went down. The second semester I worked harder to emphasize the drill and practice of the necessary background material. This increase in the drill and practice methods of study resulted in a dramatic increase in grades on traditional exams. It remains to be seen if this increase in grades was the result of a different group of students or my persistence. The struggle to integrate the learning of required concepts and the understanding of concepts is ongoing. Students also struggled with the different format of problem solving assignments. Assignments were a new format of assessment, and the first two case study assignments generated many complaints and questions. The students' work reflected their confusion; answers to questions and comments regarding evidence were short and sometimes not relevant to the questions. By the third and fourth case study, students were more comfortable with the evaluation method, and the answers and comments became more relevant. Evaluations of the problem solving assignments and of the use of the case studies to facilitate critical thinking skills are the problems needing work in the future.

Future Research

The introduced method of teaching concentrated on integrating the biological concepts into a framework relevant to real experiences in the students' lives. The purpose behind the repetition of problem solving exercises was to give students a tool to use as part of the decision making process in their lives. As part of these ongoing changes in the curriculum, further research is needed into methods and criteria for measuring scientific literacy and critical thinking skills.

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4 Math and Science Education Reform: A Community College Perspective

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When I first began teaching biology, I was very much a traditionalist. I followed the classic strategy of spouting information with the expectation that my students were learning. After many conversations with students and colleagues, and various RMTEC and other professional development workshops, my own personal teaching paradigm has shifted. I no longer believe in the "talking head" pedagogical strategy. Student retention of concepts and enthusiasm in my classes have improved, and I feel a sense of rejuvenation as a teacher. My hope is that other science faculty will experience the same renaissance that I did.

—Chris Romero, Chair, Natural and Environmental Sciences,
Front Range Community College-Larimer Campus

Front Range Community College (FRCC) is one of three community colleges that has partnered with universities as part of the Rocky Mountain Teacher Education Collaborative. The campus serves approximately 4,000 students in Larimer County, where Colorado State University is located. FRCC has participated in the collaborative and received funding from RMTEC to support the campus RMTEC initiatives.

Spreading the Word

Whenever a new initiative comes to campus, a champion or advocate is usually required to spread the word so that it has a shred of hope of catching on. Fortunately, FRCC had a champion in the form of chemistry faculty member Bill Knight, who brought to the campus his commitment to small-scale science and to reforming how we teach science. At the time RMTEC began in Colorado, our campus was just beginning to plan for and build a new science building. We were able to construct Sciplex labs that support small-scale science, small group work, and handy computer/ Internet access. Our first two years of financial support from RMTEC was used to encourage science faculty to consider constructivist teaching and to adopt small-scale science.

Roundtable Discussions

One of the lessons learned in the first few years of implementing RMTEC principles at FRCC was that the faculty needed consistent exposure to the ideas and beliefs for reformed teaching. Time to plan appropriate activities became an issue for the already busy faculty. Science Chair Chris Romero and Mathematics Chair Bill Hoard decided to enhance their commitment to RMTEC by appointing Susan Hobson-Panico, a Ph.D. student at Colorado State University, as RMTEC coordinator for FRCC. Since Bill Knight had left FRCC, Susan became the new champion for RMTEC.

Susan created a number of RMTEC Roundtables for all full-time science and mathematics faculty. Roundtables were referred to as collegial discussions, rather than as faculty development or enhancement. During the 1997-98 academic year, they focused on creating environments for teaching diverse students in mathematics and science, and usually featured a knowledgeable facilitator (in one case, a panel of students of color) who engaged the faculty in some "out-of-the box" thinking. In 1998-99, the focus changed to reform, whereby faculty from the universities in the collaborative came to FRCC to share their reform approaches. These Roundtables were usually discipline-specific, allowing faculty to meet with university colleagues who were struggling with similar issues. The FRCC faculty appreciated these intimate discussions on reform. They were important occasions because university guests were able to validate the progress of the community college faculty.

Mini-Grants to Motivate

Motivating faculty to make curricular changes in their courses is difficult in the community college environment because of time constraints, not lack of interest. Since the mission of the community college is superb teaching, faculty are often very willing to make improvements in content and delivery related to their instruction. Part of the RMTEC initiative at FRCC was aimed at faculty making changes that included more hands-on, minds-on, interactive learning. For a number of years during the project, competitive mini-grants were awarded to mathematics and science faculty. Many of these grants provided modest salary to faculty during the summer when they had time to spend on their curriculum. Additionally, some faculty were provided small sums of money to purchase materials. These grants resulted in numerous changes that are described in the science and math sections of this chapter.

Natural, Applied, and Environmental Science Steps Up to the Plate

Biology

Chris Romero, Chair of the Natural, Applied and Environmental Science (NAES) Department and instructor of biology, admits that for most of the recent history of science teaching, the focus has been on presenting students material via the lecture format, and then testing them on information from the lecture. Very little interactive work was done in the lecture portion of class. He shares with us that . . .*For the first five years of my* *teaching career, I taught using this approach.* He changed his teaching approach based on research that showed minimal retention of concepts by students who learn from lecture-type teaching. As chair, Chris also has been able to influence others to make similar changes. Dr. Idahlynn Karre, a University of Northern Colorado professor, has influenced Chris and the other general biology faculty to infuse cooperative learning activities into *General Biology I and II* courses. Some of the more successful activities include:

- **Pair Share** – In this activity, students were asked questions (for example: How do plants and animals provide necessary materials to each other?) requiring critical thinking, synthesis, or application, and given time to think about them. Then, they were asked to pair with another student and discuss their answers. Pairs then reported to the entire class what they learned. Student feedback on this activity was generally positive. They enjoyed the interactive nature of the activity.
- **Bookends** – The instructor asked students at the beginning of class to write down any questions they might have regarding the topics to be discussed that day. Students then turned to a partner and shared their questions. Toward the end of class, students revisited their questions and formulated answers based on the topics that were presented. Student feedback on this activity was also positive.They liked the manner in which the lecturer answered their questions as they listened to the material and interacted with the instructor.
- **Send a Problem/Solve a Problem** – In this activity, students formed groups of 2-4 and prepared 1-3 problems they felt would make good test questions involving critical thinking and/or analysis. Then, each group exchanged questions with another group and attempted to respond to the questions. After all groups had finished, each group reported the questions and their solutions to the entire class. As a modification, the instructor could announce to the students that some of the questions might be used on a future exam. Student feedback on this activity was very positive. They

liked having a stake in the design of their own test questions and enjoyed writing questions on their own. They also wrote questions with an emphasis on stumping other groups of students.

Student comments from classes where these techniques were used included:

I like the group activity because it adds variety to the class and gives the opinion of another person.

The activities cater to different styles of learning.

The group activity was a good way to get us thinking and involved.

I really like the mixture of lecture and group work.

In summary, Chris states,

When I first began teaching biology, I was very much a traditionalist. I followed the classic strategy of spouting information with the expectation that my students were learning. After many conversations with students and colleagues, and various RMTEC and other professional development workshops, my own personal teaching paradigm has shifted. I no longer believe in the "talking head" pedagogical strategy. Student retention of concepts and enthusiasm in my classes have improved, and I feel a sense of rejuvenation as a teacher. My hope is that other science faculty will experience the same renaissance that I did. My next goal is to complete multicultural infusion into my biology curriculum, which is an opportunity that has been provided to me through a RMTEC mini-grant.

Chemistry

Chemistry instructor Dr. Shashi Unnithan is one of FRCC's most committed RMTEC faculty members. She has focused reform efforts on two areas: development and implementation of group activities, and use of small-scale laboratory techniques. In the chemistry discipline, group activities involving problem solving (critical thinking- oriented) were developed to facilitate interaction among students. Demonstrations, using small-scale techniques, were developed and shown to students on the overhead projector. Students then discussed the demos in pairs, in groups, or as a class. They discussed what happened in the demo, why it happened, and explored "what if" type questions. To do this, the instructor asked students what they thought might happen if some of the parameters (chemicals and amounts) were changed in the demos. These demos motivated students to interact and also showed them the utility of the small-scale technique. Another activity that has been implemented is asking students, at the end of each class, to write down one concept they understood and one concept they didn't. Concepts that were not well understood were then reviewed to facilitate better understanding. Shashi believes that student reactions to group activities have been mixed, but generally positive. In her opinion, some students are still locked into the traditional lecture method and would rather sit and listen to a teacher than do more thinking-type work during class.

In the area of small-scale laboratory techniques, Shashi indicates that small-scale has been used at FRCC for approximately 5-6 years and is presently used in almost all chemistry courses. The exception is Organic Chemistry, in which small-scale techniques currently are being developed. On the first day of lab, the instructor explains the philosophy behind small-scale to students so they will gain a better understanding of techniques. This explanation includes the environmental benefits (less chemicals used, less waste) and the increased use of the techniques in industry (gives a real-world connection). During each lab period, the instructor asks students to think beyond the assigned exercise and to discuss other ways in which the techniques could be used in other experiments the student might undertake. For instance, one of the labs discusses and exemplifies strategies involved in cleaning up oil spills. Students are asked to discuss strategies and techniques and how they might be used in the real world. During the last lab period of each semester, the instructor has groups of students present one lab each to the rest of the class. This helps the students connect the entire semester together and allows them to gain new perspectives on each lab exercise from their colleagues.

Interviews with students revealed reactions to small-scale science. In the affirmative, students say they like the small-scale approach because they can do more repetitions of specific experiments, which facilitates greater understanding. They also like small-scale because it provides more diverse learning experiences, which facilitates increased retention of concepts. Some students share a more negative view, saying that they like large-scale better because they can see what is going on in the experiment more clearly. Students in introductory courses seem more receptive. This may be due to the fact that they have never had chemistry experience before. Students in higher-level courses are concerned about the transferability of their learning to the university setting. The instructor assures them that these techniques are being used at nearby Colorado State University. The other concern expressed by students is that small-scale techniques do not seem "real" and do not exemplify what is happening in industry. The instructor explains that more and more businesses are implementing small-scale because it is more cost efficient and produces less waste.

Shashi concludes her thoughts on RMTEC principles by saying, *I've changed my perspective on the classroom environment. I now view it more as a learning environment rather than a teaching environment.*

Mathematics Makes Learning More Relevant

One of the joys of working in the community college environment is the underlying commitment to teaching above all else. The Mathematics Department has long been concerned about teaching with methods that make learning relevant to students. According to Mathematics Chair, Bill Hoard, the department's major teaching focus is making math relevant in the real world. In fact, several years ago RMTEC awarded the Math Department a mini-grant to develop lab activities for *College Algebra*. Today, mathematics faculty are able to find textbooks that have appropriate hands-on activities integrated into each unit that utilize real world examples.

Recently, the Mathematics Department as a whole won a RMTEC mini-grant to create ten calculus group activities designed to bring application of key course concepts into focus. Activities are designed to motivate students to talk about real-world use of mathematical concepts they learn in class. For example, students are asked to look at an airplane flying toward them and calculate the rate of change with respect to time. This activity reinforces the concepts of relative rates, change, and positioning.

The Mathematics Department continues to add to its cadre of manipulatives used for active learning. The departmental goal of having a graphing calculator available to each student who needs one has recently been met. Full-time faculty members provide continual updates to adjunct faculty on graphing technology. Mathematics faculty use concept mapping to encourage students to express their knowledge in alternative ways.

The most significant change brought about by RMTEC to mathematics teaching methodology was the introduction of writing assignments and group activities. Mathematics faculty members now are devoted to having students use their writing skills in their classes. Some faculty members require students to keep a journal of important math words/concepts. Students have found these journals so useful, they have complained when other faculty members don't require them! The department is so serious about using writing in mathematics classes, they have trained adjunct faculty on how to get students to explain major course concepts in writing. Training includes how to motivate students to write and how to grade writing assignments.

How does the math faculty feel about the use of writing in their classes? The following discussion among full-time faculty members Chris Neve(C), Alan Dinwiddie(A), and Nancy Casten(N) reflects the impact of these activities:

N – *I have found that the writing assignments strongly affected the way students viewed the concepts of mathematics. Students who tend to be more verbally-oriented tend to gain confidence and acceptance of these ideas.*

A – *At the same time, students who are not verbal find these activities extremely difficult. They can work the problems on paper, but they find it an immense challenge to put it down in words. Once they can put it down in words they can really understand the process.*

C – *The skills they learn through their writing can be extended to their lives outside the classroom. For example, if they are required to write problem solving for mathematical concepts, they can apply the same process to a business/office environment.*

N – *Although communication is a key to life's relationships, problem solving is extremely important. I've tried to put together group activities that would incorporate problem-solving skills and the techniques used in the classroom.*

C – *The introduction of group activities has turned the classroom into a more closely-knit learning community. After working with each other, students naturally form study groups and work together outside the classroom.*

A – *I have tried to use group activities as a motivation to establish relevancy of the current math topic. One example is a group activity I developed as a result of a phone call from a former student about how to pack shipping crates going overseas.*

N – *And that is exactly why group activities are very difficult to construct and time-consuming to put together.*

A – *The more relevant they are, the more time-consuming they are. Speaking of time-consuming, I have to admit disliking writing assignments, because they take up a great deal of time due to difficulty in grading. There are many ways to express the same concepts. In spite of this, I am convinced of their tremendous value.*

C – *Yet the time put into grading pays off in the end, since you see improvement in writing skills through the semester.*

A – *I have found it interesting that you can often notice when students have been in a previous class that required writing assignments.*

N – *In working with students in both activities, I have become aware of the differences in learning styles between genders. Females tend to be intimidated and confused when it comes to group activities, yet they gain real self-confidence when doing writing assignments. Males tend to jump right into group activities, exploring new ideas, yet they shy away from verbalizing the same concepts.*

C – *Minority students sometimes gain more from group activities, because they have one-on-one contact with the instructor in the classroom and this eases their apprehension toward the course.*

A – *The workshops we have had with faculty have not only helped them understand the rationale for group activities and writing assignments, but have also helped us to come up with new ideas as we discussed them.*

In summary, Alan, Nancy, and Chris say that they all feel the writing assignments and group activities have been beneficial. They believe group activities have added energy to their classrooms and allowed them to reach diverse learning groups.

Bringing Teaching Careers Into the Peripheral Vision of Community College Students

For the first time ever, FRCC is offering students the opportunity to learn more about the teaching profession. With a grant from RMTEC, a new 2-credit course, *Introduction to Teaching: K-12*, has been added to the curriculum. Students in the class will acquire expository knowledge of various topics such as: how schools function, effective teaching methods and learning strategies, diversity and multiculturalism, technology in education, alternative choices for education, legal and ethical issues for teachers, and teacher licensure. The course is team taught by a public school science teacher and an adjunct community college faculty member. FRCC has also begun a new club for students interested in pursuing teaching as a career. So far, both are big hits; the course is oversubscribed, and the club is meeting at two separate times to accommodate student schedules and interests.

RMTEC a Success at Front Range Community College

The RMTEC initiative at FRCC has created more reform than anyone ever dreamed. With the initial vision of Bill Knight, and continuing with the leadership and commitment of Chris Romero, Shashi Unnithan, Bill Hoard, Chris Neve, Alan Dinwiddie, and Nancy Casten, the campus has improved teaching, addressed diversity, encouraged community college students to think about becoming teachers, and most importantly, transformed its math and science classes into keener learning communities.

5 Investigating the Role of Standards-Based Education in a Pre-Service Secondary Math Methods Course

Lawrence Mark Lesser
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. . .in using a rubric, the teacher must make a conscious decision on what criteria 'real understanding' will be based. In this light the process becomes more important than the actual correct answer, and it is this process which indicates real learning of the concepts.

—Student comment on using rubrics

As homework assigned the previous class period, math methods students were asked to attempt the Grade 11 performance assessment called "Shoelaces" (from the 1995 New Standards project, adapting the presentation of Linnen and Pollard-Cole, 1996) as well as reflect upon a 4-point rubric written for scoring a general "on-demand performance in mathematics." At the next class period, the methods instructor handed out and facilitated discussion on the following specific 4-point rubric tailored to the particular task of modeling shoelace length needed for sneakers with a given number of eyelets:

4: We clearly see how students derive a rule that provides an appropriate model for the shoelace: in the form $y = ax+b$, where x = number of holes, a = amount of lace associated with each hole, and b = constant amount needed for the bow. Formula, table, and graph are each present, correct and consistent. Reasonable estimate for length of shoelace.

3: Explanation may lack clarity. There may be minor inconsistencies between formula, table, and graph. Reasonable estimate for length of shoelace.

2: One or more of the formula, table and graph representations are not fully given, developed, or discussed. Resonable estimate for length of shoelace.

1: No appropriate strategy shown. Reasonable estimate for length of shoelace may not be given.

At the beginning of the semester, four of the seven students had reported experiencing a performance-based task and use of a rubric at least once in their prior mathematics courses. Words such as standard and rubric can vary greatly from person to person, however, and in any case the students had not had the opportunity to be on the administering end of a rubric.

Each of the seven methods students then independently rated (with the above 4-point scale, giving a brief justification for each rating) each of seven anonymous high school student attempts provided by the instructor. During the ensuing whole class discussion, students were visibly impressed at how consistent their ratings were with each others' (each time, the majority of the class had given a common rating, and only twice was any one student's rating of a particular paper two rubric points different from another student's rating of the same paper), especially considering the limited time they had been given, and the fact that they had not been given anchor and calibration papers. The class agreed that once a rubric is defined for an open-ended task, a rubric score is more reliable than scoring a 10-point problem on a typical math exam. In a follow-up written reflection, Biff (a pseudonym) perceptively noted other advantages of rubrics:

. . .in using a rubric, the teacher must make a conscious decision on what criteria 'real understanding' will be based. In this light the process becomes more important than the actual correct answer, and it is this process which indicates real learning of the concepts. Scoring a problem up to 10 points really ignores the process unless the student misses the answer. It is possible for the student to get the correct answer and have little understanding of the process or reasons for the methodology. Well-crafted rubrics can correct this problem by having the teaching (as well as training the student) focus on the essential elements of understanding and communication.

Purpose and Method

In 1993, the Colorado General Assembly enacted HB93-1313, requiring K-12 public school districts to establish standards by January 1997 at least as rigorous as the Colorado Model Content Standards (the state mathematics standards were released June 1995). Today's standards-based environment was not in place when many current pre-service secondary teachers were in high school. It is therefore especially critical that as many university classes as possible, particularly methods classes, discuss and model teaching in a standards-based environment.

For this case study, the author analyzed artifacts (e.g., exams, short essays and other written assignments) and observations (including participant observation during the methods class itself as well as nonparticipant observation in the field while supervising clinical experiences) throughout the fall 1998 semester. The author also had an outside researcher conduct nonparticipant observation of a particular methods class period involving the performance assessment activity described earlier. This use of multiple methods, multiple data sources, multiple cases and multiple researchers supports the rigor of the study (Reid, Robinson, & Bunsen, 1995).

Background

Many experiences have supported the author's background in standards-based education. During the 1994-95 school year, he worked as a faculty content specialist (with teachers from Aurora Public Schools, Colorado Coalition of Essential Schools, University of Colorado-Denver, Gateway and Skyview High Schools) to develop mathematics content standards, indicators and a rubric as part of the Colorado Commission on Higher Education (CCHE)-funded grant, "Next Step: K-12 and Higher Education Working Differently and Together" (Griffith, 1996). During the 1996-97 school year, he developed a standards-based university course in introductory statistics for the CCHE-funded Educational Technology Improvement Project (Lesser, 1998a), which added profound clarity to all of his subsequent teaching. The author's focus and dissemination (Lesser, 1998b) on standards-based education naturally complemented the RMTEC project goals of inter-institution collaboration and improving preparation of pre-service teachers. The author's own professional development was arguably the most important factor in reforming the course (Cruz, Jr. & Reynolds, 1998; Palmer, 1998).

During the three semesters (the first time was team-taught with Presidential Award-winning middle school teacher John Putnam) the author taught the secondary math methods class (MED 441) at the University of Northern Colorado (UNC), he refined and revised the course to address and incorporate the many roles that standards play. The standards the author wrote (see Figure) for the course syllabus reflect awareness of local, state and national mathematics content standards as well as standards and goals of the UNC Secondary Professional Teacher Education Program (the secondary PTEP clinical experience course is a co-requisite for the math methods course), the Rocky Mountain Teacher Education Collaborative (RMTEC), the Colorado Educator Licensing Act of 1991, the teacher education literature, and input from other RMTEC methods instructors (through individual communication and from the January 1998 RMTEC methods team meeting).

Figure: Standards for the Secondary Mathematics Methods Course
(from Dr. Lawrence Lesser's MED 441 syllabus)

To help pre-service mathematics teachers. . .

1. . . .become fully active team-players in the K-16 education community (including parents, students, peers, etc.), and become more aware of professional organizations, professional dress and deportment, availability of resources, literature, expectations, habits of mind, and how these can enhance classroom teaching.
2. . . .develop purposeful and appropriately innovative lesson plans, curricula and pedagogies and understand how they are connected to each other (pedagogical content knowledge) and to the NCTM Standards.
3. . . .more appropriately address issues of gender, ethnicity, learning style, special needs, language abilities, and other variabilities among students so that all students may achieve success in a significant common core of mathematics. (Also, teachers will appropriately handle humor and value-oriented issues in the classroom.)
4. . . .appropriately choose, use and explain a variety of enthusiastic approaches to teaching mathematics (e.g., cooperative learning, technologies, manipulatives, inquiry-based approach, problem solving, student-collected data, projects, reading, writing, speaking) that motivate students who arrive with a variety of learning styles, attitudes and misconceptions (about mathematical content and/or the nature of mathematics itself).
5. . . .develop understanding of integrated curricula that makes connections within mathematics and/or between mathematics and science and/or to real life.
6. . . .appropriately choose and use traditional and performance-based approaches to teacher-assessment, peer-assessment and self-assessment, that are integrated into lesson plans and aligned with objectives/standards.
7. . . .learn strategies for classroom management that create an effective classroom climate where all students are consistently on-task and feel safe to be creative, to take active responsibility for their learning, and to engage in metacognition and critical thinking.
8. . . .(learn how to) learn from their (and their peers') prior and/or concurrent reflection, student teaching and observation experiences in middle and secondary schools and micro-teaching in the methods classroom, increasing self-awareness as a reflective practitioner of one's teaching philosophy and pedagogical tendencies and how to integrate them with those of the school.
9. . . .solidify ability to relearn/learn any necessary mathematical content knowledge using available resources.

The methods course incorporates a great deal of discussion and assignments about the various standards, including assignments that connect to students' field experiences in the schools. Such connections are intended to minimize problems such as the "two-worlds pitfall" articulated by Feiman-Nemser and Buchmann (1985). For example, one individual written assignment, which will be mentioned in greater detail later, involved interviewing an in-service classroom teacher about topics such as math content standards. Also, the author had student mini-lesson presentations during the methods class evaluated by the teacher, peers, and the student himself or herself, using the same observation forms utilized in clinicals. Many methods lessons were driven or launched by students sharing their observations or experiences from recent clinicals. These more explicit connections between methods and clinical experiences grew out of a conscious decision, implemented with the fall 1997 semester, to provide a more integrated experience by having the department's clinicals person also teach that semester's methods course. During both semesters of 1998, the author was a partner school faculty member at Greeley West High School, teamed with a colleague (Dr. Kathy Cochran or Ms. Patricia Brooks) from UNC's College of Education.

In addition to actual assignments, the overall environment of the methods course offers many opportunities for connections to standards-based education. The "model classroom" where the math methods course is taught has a poster of the state standards and indirectly supports them with other posters, computers, manipulatives and hexagonal cooperative learning tables that fill the room. National (NCTM 1989) and Colorado mathematics content standards were among the links on the instructor's course home page: http://etip.unco.edu/courses/MED441/MED441.htm. Other standards-related articles and materials (e.g.,NCTM 1995) were put on reserve in the library, including the draft of the Standards 2000 document (NCTM 1998) right after its release in the middle of the semester. The primary textbook (Cangelosi 1996) integrates national standards (NCTM 1989, NCTM 1991) frequently throughout text and exercises and summarizes them in the Appendix. The course also required students to attend and report on a significant portion of the Colorado Council of Teachers of Mathematics state conference meeting, which not only gave them more exposure to curriculum and pedagogical ideas driven by the Standards, but also supported UNC's Secondary PTEP Professional Behavior Standard.

Emergent Issues and Observations

In completing the assignment (Cangelosi, 1996, pp. 405-406) of interviewing in-service teachers, students encountered a healthy and critical appreciation of how the NCTM standards impact the classroom. Those in-service teachers gave the national standards general praise, citing their greater specificity than Colorado standards and their focus on goals over techniques, but leavened by assertions such as: (1) *it's hard NOT using the Standards in every lesson [because of their generality]*; (2) *teachers can't do all things that the Standards propose with every student, because all students learn differently*; and (3) *the problem is and always will be — good teachers are already doing the things addressed in the Standards and poor teachers are not.* Hearing such feedback from practicing teachers seemed to give the students greater permission to critically examine the assumptions, strengths and weaknesses of the Standards themselves. During subsequent class meetings, students raised and discussed numerous questions or conceptions about standards, such as: Are there several ways to "meet" a standard? Is a standard something to "meet" or "exceed"? What is the best balance between universality and specificity when writing a standard? When, if ever, should the Standards' call to "deemphasize" certain topics be interpreted as "eliminate"? Is there enough time and resources to address all of the standards without eliminating some topics? How can high school students be held to NCTM standards for high school students if they did not meet the NCTM standards for earlier grades? How can "mathematics for all" also meet "the needs of students who have deep interest in pursuing mathematical and scientific careers"? How can something as general as the Standards imply specific teaching practices?

While the author was able to concretely address the last question, for example, by bringing in and discussing observation forms from Stonewater (1996), students quickly gained a deeper appreciation for the roles of values and assumptions in their questions, and therefore realized they would not easily reach complete agreement. Students had new appreciation for the potential and the limitations of phrases such as "meets NCTM standards" adorning items for sale at exhibit booths at the CCTM conference in October.

Discussion of standards truly became a climb up the ladder of Bloom's taxonomy (1956). For example, during the month of September, students spent much time learning what the standards actually say. As a result, one of their observations was that half of the standards in the current NCTM (1998) draft are truly standards about process rather than content. In October, students attended their first mathematics education conference and were applying the standards to lesson plans they were writing. During one lively class meeting, students explored and compared eighth-grade TIMSS (Third International Mathematics and Science Study) lessons from America, Japan and Germany (e.g.,http://nces.ed.gov/timss/video/jimvid1.htm). By November, they were coming to grips with the philosophical and evaluative nature ultimately underlying the standards. This process gave students more appreciation for the importance and impact of having objectives on local and global levels, which they directly expressed during a metacognitive inventory addressing Course Standard #8 (see Figure) and a "mock job interview" exercise held near the end of the semester. This exploration culminated by having them write responses to Reader Reactions #2 and #9 in NCTM (1998) as the take-home part of the course final exam.

From the spring 1998 data independently compiled by RMTEC Project Evaluator Dr. Jeff Gliner, the item most pertinent to standards-based education asked students to respond with "did not happen," "happened and somewhat helpful," "happened and very helpful," or "happened and extremely helpful" to the phrase "consistency between course concepts and state and national standards in math, science and education." All nine students from the spring 1998 semester responded to this item with one of the two highest ratings, including six students giving the highest rating.

From student reflections on their clinical experiences, it was clear that students recognized that a key to success was taking initiative in actively processing each teaching experience or observation as the NCTM (1991) recommends in the Professional Standards. As Loretta put it,

The frustrations of my first experience had made me more assertive towards the fact that if I wanted to get something out of this I had to be persistent with inquiry. . . Being able to actively participate and have responsibility during the observation times is what has help[ed] me to realize that I cannot just copy a teacher but have to find and define my own teaching style.

Indeed, Loretta made a breakthrough in her student teaching when she was given feedback from the author about connecting more with her students, who were sitting only in the rear rows of the classroom, quite removed from the teacher whose back was often turned to write on the chalkboard. Loretta obtained dramatic improvements in classroom management after she moved the more desirable desks closer to the front of the room and began using an overhead projector so she could maintain more eye contact. While her strong personal commitment and content background helped her achieve success, Loretta expressed a concern for her peers who had less: *I will spend the time necessary to acquire the skills to implement these standards. The question that I have is: what about the students who study mathematics that make it barely from one course to another but still end up mathematics teachers?*

Discussion

In past semesters, students arrived at the methods course claiming to be unaware of the standards. Apparently, students were indeed being exposed to the concepts and processes of the standards in many of their university math courses, but the explicit connections were not being made.

Students began most recent semester's methods class (fall 1998) with all but one professing at least moderate familiarity with the standards, possibly due to increased connections being made in the sequence of STEP classes and seminars in the College of Education, if not also in the Department of Mathematical Sciences.

It may not be coincidental that this most recent semester, the one with the heaviest "dose" of standards-based education and the one that incorporated the hot-off-the-press NCTM (1998), also produced the most motivated students. At the beginning of the semester, none of the seven students were members of CCTM or NCTM, or had attended a professional meeting of mathematics teachers. During the term, all seven students attended and participated beyond what was required in the annual state conference in Denver, and one student voluntarily attended a Colorado Board of Education meeting as well. Several students became national NCTM members and two even drove from Colorado to Reno, Nevada in November for the Western Regional NCTM conference!

Closing

The methods students further demonstrated the mature appreciation they had attained for the strengths and weaknesses of the newest Standards document (NCTM 1998) on their responses to Reader Reactions #2 and #9 for the take-home part of the course final exam. The students gave answers that made connections to their field experiences and often offered important suggestions or questions. Biff suggested adding a *Principle of Qualitative Reasoning* as *the real fabric that binds math with all the other disciplines, not just to the sciences.* Bradley suggested adding *an additional principle that deals with the learning of mathematics outside the classroom such as: parent involvement programs, tutoring programs, extra-curricular math activities (math contest, math fairs, etc.).* Making connections to his clinicals experience, Bradley also raised serious concerns about equity issues (*Why is it that 75 percent of the students in my remedial prealgebra class are Hispanic when the demographic breakdown at the high* *school is about 75 percent Anglo and 25 percent Hispanic?*) and access (*Just go to a class at [my school] where even graphing calculators don't exist. . .Where is the Technology Principle for the schools in low to middle class districts?*).

Though they likely had greater current knowledge of the Standards by this point than many in-service teachers, few students seemed comfortable with the idea of also sending their Reader Reactions to the NCTM as part of the organization's solicitation of feedback from multiple constituencies. Nevertheless, the degree to which students had become empowered with initiative and engaged in the mathematics education community dialogue has gone a long way towards achieving the first two methods course standards (see Figure), and, more importantly, towards a meaningful career with the potential to impact and inspire students and colleagues alike.

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6 Meeting the Challenges of Diversity in a Context of Reform

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How privileged I feel to be here. How unusual to share topics "unspoken" in most circles with a group of people I hardly know — with students, professors, men, women, Chicanas, Cubanos, African Americans, European Americans, and others from varied backgrounds. It takes courage. It takes honesty. It takes risks. Thanks to the group. If not now, when? If not us, who? I leave with a feeling of hope that equity here is a strong shared cause. I am glad to be a part.

—Comments from participant in Equity Study Leadership Group, Fall 1998

One of the major goals of the Rocky Mountain Teacher Education Collaborative (RMTEC) was to recruit and retain those sensitive to issues of women and ethnic minorities into teaching careers in the fields of mathematics and science. Components of this goal included (1) promoting activities to increase the number of women and ethnic minorities who are majoring in mathematics and science entering the teaching profession; and (2) enhancing the skills of faculty working on undergraduate reform initiatives in mathematics and science to engage in more culturally-sensitive teaching. Six colleges and university campuses participated, with each identifying a number of strategies to meet the goal. Campus-based teams of faculty (chemistry, mathematics, earth resources, biology, physics, education and diversity), and public school Teachers-in-Residence focused on course development and professional development activities for faculty. These teams also initiated efforts to recruit and retain teacher candidates from underrepresented groups.

The teams quickly learned that reform efforts were different across the six campuses. The politics, personnel, and priorities of each campus created different professional cultures that were more or less responsive to change. Change literature indicates that reform takes time, often five years or more to institutionalize from the beginning of the effort to accepted practice (Fullan, 1991). Each reform must have an institutional leader and take the path that works best within that institutional culture.

Scholarships

Each campus awarded scholarships to women, students of color, and others committed to fostering diversity, who were majoring in mathematics or science, and indicated they would like to become teachers. These monetary awards were provided through a supplemental grant from the National Science Foundation, and proved to be the best incentive institutions had to recruit and retain students in the program. Further funding was sought from private sources to continue RMTEC scholarships when the grant ended. Awards were reviewed each year and adjustments were made for graduating students, students with low GPAs, and student transfers into mathematics and science teacher licensure programs. Scholarship moneys were shared among RMTEC participating institutions based upon the diversity of their student population, number of applications, and consideration of greatest need or likelihood of achievement.

RMTEC has supported over 100 students, including 60 ethnic minority students. Not only were the scholars encouraged to become teachers in science and mathematics, they also were asked to help recruit others from underrepresented groups to become teachers. As well, RMTEC scholars were asked to serve as volunteers at the Colorado Science and the Colorado Math Educators' conventions. Many also provided community service to schools in their area and worked with students who needed help in math and science.

Faculty Training

As a second component of the diversity goal, RMTEC encouraged professors to become sensitive to the needs of women and people of color within their classrooms. Faculty development seminars, sessions at the annual RMTEC faculty development workshop, brown bag lunches, and other dissemination efforts were offered as a means of enhancing the understanding and sensitivity of faculty. Individual campuses supported various efforts aimed at serving students who potentially needed additional resources, such as mentors or targeted faculty advisors who were sensitive to women and students of color. Professors also developed a diversity workshop for students in the program and invited all RMTEC scholars to participate in the workshop.

RMTEC sponsored several faculty teams with representatives from various campuses to participate in the Equity in Mathematics Education Leadership Institute (EMELI), a National Science Foundation sponsored project directed by Dr. Julian Weissglass of California. Teams were comprised of RMTEC principal investigators, university and community college faculty, teachers-in-residence and local school district personnel.

Based on campus culture and initiatives that already existed on the various campuses, each focused on different initiatives to meet their individual and faculty needs. Both the University of Northern Colorado and Metropolitan State College focused efforts on pre-professional development modeled after the aforementioned EMELI training. Colorado State University focused faculty development efforts through the Multicultural Infusion Project, an already existing program. Each community college sent faculty to the EMELI training and then provided its own campus-based professional development activities.

The latter part of this chapter will present an overview of the Multicultural Infusion Project at Colorado State University. Following, a case study of the use of Equity in Mathematics Education Leadership Institute (EMELI) training on the Metropolitan State University campus will be discussed, concluding with a University of Northern Colorado faculty member's perspective of the EMELI training, particularly as it relates to the scholars initiative.

Multicultural Infusion Project

The Multicultural Infusion Project at Colorado State University provides professional development experiences for faculty to assist them in making changes in content and pedagogy so courses are more inclusive of all students. The project has involved more than 140 faculty participants and has completed its ninth year. It is based on the premise that most faculty members and administrators in higher education are not prepared with the skills to infuse multicultural issues and content into the overall curriculum or individual courses. Many faculty have spent little time reflecting on their own thoughts, feelings, beliefs and values related to race, ethnicity, and other human differences. Faculty who are aware of their own misperceptions, beliefs, values and distortions can better work with students to examine their biases and beliefs. Many faculty choose to address multicultural issues by bringing in a guest speaker, having a panel of experts or by showing a movie. Much of this approach focuses on keeping diversity separate from the curriculum. As a result, diversity is often perceived as an "add-on" or "single focus issue."

Instead of spotlighting diversity in the manner described above, the infusion project seeks to infuse a course with a multicultural perspective. This entails integrating subject matter into the total course through reading assignments, homework, and various learning activities. The challenge, then, was to create a professional development activity for faculty so that they could feel comfortable in changing their own courses and thus impact the undergraduate and graduate curriculum on campus.

Process

Academic faculty are recruited each year to participate in the infusion project. Invitations are offered via targeted letters to faculty, personal contacts, and announcements at new faculty orientation. Department heads and deans are also asked to encourage faculty to participate.

Faculty who are interested in becoming involved in this professional development opportunity are asked to complete an application, provide information about why they would like to participate, and indicate which courses they plan to target for infusion. If more faculty apply than can be accommodated, the selection process stresses diversity among faculty participants, in ethnicity, gender, academic rank, positions on campus, and content areas represented.

Participants are asked to make a year-long commitment to the training by signing a contract agreeing to the following actions:

- Participate in all professional development sessions held over the course of the academic year and read various assigned readings in preparation for meetings.
- Infuse a course to reflect a diversity perspective the semester following completion of the professional development activity.
- Develop new educational materials needed to support the course revision, including readings, instructional aids, resources, etc.
- Conduct appropriate outcomes assessment to reflect changes in student learning.

Resources

Historically, faculty participants have been provided an $800 stipend for participating in the project, and $300 to purchase resource materials needed to make course revisions. We believe, however, that most would have participated without the $800 stipend. A resource bibliography is assembled annually and resources are shared with other faculty.

Professional Development Activities

Over the course of an academic year, project facilitators plan professional development activities related to numerous topics. Group sessions include: an orientation meeting, a retreat for 1 1/2 days early in the fall, a second 1-day retreat (early in the second semester), and a series of 2-hour meetings held twice a month throughout the school year. A summary of topical focus areas can be found in the following figure.

Figure: Topical Outline for Training

I. Theoretical Starting Points: Race, Ethnicity, Culture, Prejudice, and Discrimination
   1. The biological and social bases of race and racism: history and current knowledge
   2. The concept of ethnicity: categorical and transactional paradigms
   3. Culture and human behavior

II. Socioeconomic Class Differences, Race, Ethnicity, and Culture
   1. Does culture explain behavior?
   2. The significance of social class
   3. The complexity of human behavior: social class and culture as intervening variables

III. The American Ethnic Experience
   1. Single melting pot, triple melting pot. Anglo conformity, or cultural pluralism
   2. Ethnic myths: the Jewish Horatio Alger story
   3. Why do certain groups make it and others do not? What is different about Blacks, Mexican Americans, Puerto Ricans, and Native Americans?
   4. Behavioral characteristics of groups: the use and abuse of cultural generalizations

IV. Ethnic Identity as a Psychological Reality
   1. They and we: ethnocentrism and the process of ethnogenesis
   2. The uses of ethnic identity: flexibility and manipulation
   3. The nature of prejudice and discrimination
   4. Growing up different: the acquisition of a public identity
   5. Race, ethnicity, and gender: the experience of non-Anglo women

V. Other Issues
   1. Demographic projections and implications for higher education
   2. Approaches to meeting the educational needs of ethnic/racial group members
   3. Pedagogy: learning styles and their interface with race/ethnicity
   4. The experience of racial/ethnic group members in higher education
   5. Affirmative action and equal opportunity

(Baez, Oltjenbruns, Miller, MacPhee— Project Training Manual)

Although facilitators work from a topical outline, training sessions are modified each year to meet the needs of participants. The project has used the text, *Multicultural Course Transformation in Higher Education — A Broader Truth* (Morey & Kitano, 1997) during recent years. The use of this text has facilitated discussion of changes that faculty can make in content, instructional strategies, assessment of student knowledge, and enhancement of classroom dynamics.

Another major goal of the project is to create a climate that is welcoming and safe for all participants. A crucial step toward accomplishing this goal is to acknowledge that ethnocentrism, racism, and prejudice are part of the human condition. The group comes to realize that no one is immune from the attitudes and behaviors that lead to intolerance and discrimination. Facilitators encourage all participants to learn and struggle together in an environment of mutual respect, in which all ideas are open to exploration and may also be challenged.

One very powerful experience for enabling faculty participants to become more aware of both the physical and psychosocial environment is to engage a student panel in a discussion of their campus experiences. These interactions reflect what has made students from many different backgrounds feel comfortable and included in classrooms or, by contrast, what has made them feel minimized and excluded. Two videos which have also been utilized as background for discussion regarding issues of inclusiveness and exclusiveness are *The Color of Fear* (Munuah, 1994) and *Skin Deep* (Reid, 1995).

Another goal of the project is to help faculty build a knowledge and skill base related to the rationale for transforming the curriculum, general issues related to diversity (e.g., exploration of one's own values, belief systems, feelings, biases): understanding of various learning styles and pedagogical strategies that enable faculty to more effectively engage students in learning. Enhancement of knowledge and skills is accomplished through reading a wide range of materials, viewing videotapes and discussing ideas in various contexts with other faculty and students. In addition, participants interact with faculty who have already infused courses to hear their recommendations and specific ideas for curricular change, as well as to learn about the challenges and outcomes of their experiences.

While discipline-specific information is clearly needed for an individual faculty member to infuse a multicultural perspective into a particular class, this knowledge base is derived from an individual's review of one's own professional literature base and one-on-one mentoring activities. Past participants and facilitators are available to provide concrete examples of how this review may be done.

Outcomes of Project

Faculty Outcomes

Faculty participants in this project are sufficient enough in numbers to have become a critical mass of committed people who have made enhancement of diversity primary in various units' curriculum reform efforts. Faculty who initially agree to change one course often end up transforming their entire teaching, research, and service effort.

Hughes (1995) reported that faculty who had participated in the multicultural infusion project felt more confident in dealing with multicultural issues in the classroom. She used content analyses techniques to analyze responses given on a survey that asked faculty to explain how the project affected their teaching, research, and service. In analyzing responses from the 19 past participants (from 1990-1993) who comprised her sample, Hughes found that the faculty reported an increased awareness, appreciation, and understanding of diversity issues as a result of their participation in the project. Faculty reported that taking part in the project had caused them to view the world differently, so they felt it imperative to infuse additional courses with a multicultural perspective (above and beyond the course they had originally targeted for infusion).

Faculty participants in this study (Hughes, 1995) also reported a very positive reaction to the opportunity to come together to talk about both course content areas and a multiplicity of teaching strategies. Faculty admitted to being fearful of infusing diversity into their courses prior to participation in the project and explained the training sessions gave them confidence and support to experiment with different strategies and use other participants as sounding boards for ideas and feedback.

Student Outcomes

Research involving students participating in infused courses indicated that they have grown in measurable ways from curricula that have been transformed as a result of faculty participation in this Multicultural Infusion Project. MacPhee, Kreutzer, & Fritz (1994) conducted an outcomes assessment project related to changes in students' attitudes over the course of a semester, comparing those in courses that had been infused with a multicultural perspective to a control group of students taking general studies courses that had not been infused. Students were given a pretest and a posttest using a number of attitude measures. Those who had taken courses from faculty who had participated in the infusion project decreased along various dimensions related to racism as compared to students in the control group sections.

In 1997, the Multicultural Infusion Project was awarded Colorado State University's award for Outstanding Contribution to Diversity. This professional development opportunity has become institutionalized and is supported by the Provost's Office.

Case Study: Preparing Teachers for Leadership in Equity

Introduction and Purpose

How privileged I feel to be here. How unusual to share topics "unspoken" in most circles with a group of people I hardly know — with students, professors, men, women, Chicanas, Cubanos, African Americans, European Americans, and others from varied backgrounds. It takes courage. It takes honesty. It takes risks. Thanks to the group. If not now, when? If not us, who? I leave with a feeling of hope that equity here is a strong shared cause. I am glad to be a part.

These are the words of a participant in an Equity Leadership Study Group during fall 1998, at the conclusion of the first session. Fifteen pre-service teachers completing the licensure program at Metropolitan State College of Denver (Metro), a veteran teacher from the Englewood Public Schools, and several professionals from institutions of higher education participated in five 3-hour sessions focusing on issues of equity in education.

The purpose of the study group was to prepare pre-service teachers for leadership roles in educational equity. This case study examines the personal and professional growth of participants through the sessions. The need for both the study group and the case study arises from the increasing urgency to prepare future teachers for our nation's schools. As educators in teacher preparation programs, we are coming to realize that we must prepare new teachers for effectively engaging students and other educators in real conversations about their beliefs and values related to equity, in addition to preparing them to design and implement curricula which infuse diversity and multiculturalism in their own classrooms and schools.

Diverse and multicultural instructional content encompasses full and thorough infusion of the contributions that all members of society have made, including those who are now excluded and dehumanized through various forms of bias in curricular materials and programs (Cruz-Janzen, 1998-99; Sadker, D. & Sadker, M., 1997). Diverse and multicultural pedagogy entails instructional processes that meet the educational needs of diverse learners, including forms of intelligence, learning styles, abilities and disabilities, etc. Succinctly stated, education must be inclusive of all students in our schools, and particularly those who have been excluded.

This inquiry was guided by three overarching questions:

- How can we best prepare future teachers to support the educational needs of all students, especially those currently underrepresented in areas such as mathematics and science?
- How can we best prepare future teachers to integrate equity within all areas of their instruction?

- How can we best prepare future teachers to become equity leaders within their schools, districts, and communities?

Process

Beginning in fall 1996, a six-member team comprised of faculty from Metropolitan State College, Aims Community College, Community College of Denver, and the University of Northern Colorado, and a high school math teacher from the Denver Public Schools, participated in six 5-day equity sessions over a 2-year period through the Equity in Mathematics Education Leadership Institute (EMELI). This national equity institute was funded by the National Science Foundation (NSF) under the direction of Dr. Julian Weissglass of the University of California, Santa Barbara. Our team, EMELI 4, was sponsored by the Rocky Mountain Teacher Education Collaborative (RMTEC) as partial fulfillment of the diversity goals of the project.

Student Equity Group

It was agreed that upon completion of the training, an initial team effort would be to prepare pre-service teachers to take on the challenge of promoting equity in mathematics and the sciences in public schools. The Fall 1998 Equity Leadership Study Group was funded through RMTEC, the Provost Incentive Grant (Metro), and Diversity Initiatives Grant (Metro). Fifteen students were selected, ensuring diversity across gender, race, and ethnicity. Seven participants wanted to take the study group for credit, so a course was created. Sessions were co-facilitated by members of the EMELI team. A significant portion of the project's funding was allocated to materials for the students, who could then use these resources to continue their work as equity leaders in the public schools.

Topics for the sessions were:

- The Meaning of Equity and Dealing With Racism
- The Meaning of Equity Leadership
- Addressing Gender Issues and Homophobia

- Internalized Oppression
- A Call for Educational Change Leadership

Sessions were based on the equity structures Constructivist Listening, Dyad, Support Group, Personal Experience Panel, Small Group Discussion, and Reflections. They were grounded on the notions that all educators are leaders, and the structures enable each person's leadership to be supported. Each structure is designed to empower the speakers, hear the stories of participants, increase the listener's understanding of difficult issues, and help attach significance and commitment to particular issues. They allow participants the opportunity to: 1) discuss issues as they individually construct their own understanding, 2) hear another person's viewpoint, 3) provide for reflection to clarify their own thinking, and 4) help build alliances as they listen to one another's thoughts and feelings about the school situation and implementing change. The equity structures are framed along specific, inviolable, guidelines:

- Each person is given equal time to talk.
- The listener does not interpret, paraphrase, analyze, give advice, or break in with a personal story.
- Confidentiality is maintained.
- The talker does not criticize or complain about the listener or mutual acquaintances in his or her turn.

Constructivist Listening allows individuals to construct meaning and deal with their feelings through nonjudgmental communication that takes place in dyads, support groups, personal experience panels, and small discussion groups.

Some participants expressed initial discomfort with the structures' guidelines, finding them rigid and artificial. During the first session, we spent time discussing and listening to responses to questions such as: 1) Describe a time when someone listened to you attentively without analyzing and passing judgment on what you said. How did it feel?; 2) When was a time you listened well to someone?; and 3) Describe a time when you started to talk about an experience, problem, or feeling and someone interrupted you or did not pay attention. How did you feel? These discussions helped participants understand the importance of the guidelines in facilitating the safe environment required for honest and nonjudgmental communication. Representative comments from participants will be interspersed in the following descriptions of equity sessions.

Listening to someone else talk uninterruptedly is much easier than talking myself and knowing that someone else is listening.

Most participants left the first session with an understanding of the equity structures and their power in helping people of all backgrounds heal from the oppression they have experienced. Furthermore, they realized that we become oppressors as a result of having been oppressed; that we all — Whites/European Americans as well as persons of color, males and females of all backgrounds, persons of different sociocultural backgrounds — have to come to grips with our position as oppressed and oppressors.

I came today because I wanted to learn what to do. I always hear about problems with equity but no one says what to do. Tonight I learned what to do. I need to talk and I need to listen.

During the second session, we explored the meaning of equity leadership while reviewing equity structures. Again, initial uneasiness evolved into increased confidence that, *Leadership is no more and no less than taking responsibility for what matters to you.* (Weissglass, 1994, p1). Participants began to see themselves as leaders. Their increased self-perception in this capacity became, simultaneously, a surprising and empowering awareness.

I see myself as a leader. I have never done that before. I am amazed to realize that. I know I can make a difference and I believe the difference I make will be like a pebble thrown in the water with circles that reach to the shores. I know we have a long way to go, but we are here and we all can reach 500. I have hope.

The third session dealt with gender issues and was highly emotional as the nation grieved and felt shame over the senseless and brutal murder of Matthew Shepherd, a young gay man. A tragic national event brought to the forefront a highly sensitive and often avoided topic. We mourned our loss of humanity and compassion for one another as fellow human beings. The group spent most of the evening discussing homophobia and the immense, yet greatly unknown, impact it has over children's lives. We discussed how it affects us all.

Stand up to homophobia in the classroom. When you don't, you help support the violence. Act, do something to support a fellow human being. Remember, next time the victim will be you. Stop the intolerance. Act. Do the right thing.

Tonight was by far the most emotional night for me. Homophobia is such a difficult subject for me because I have seen the pain it causes for my family, friends, students, and co-workers . . ..

By the fourth session we had created more formal and structured support groups. Participants felt they were ready for prolonged commitment to the other group members, and expected the same in return. Criteria for support group membership varied but students considered things such as work and school schedules, physical proximity to campus, and travel requirements. By evening's end we had created three support groups.

On the last night, each student received a personal timer, and something unique, rather unexpected, transpired. As the perceived leaders, the group co-facilitators had handled the timers but now students had their own. Possession of their own personal timers appeared to solidify their status as equity leaders. It was, indeed, a very empowering moment. Visibly excited about creation of their support groups, they exchanged phone numbers and began to schedule group meetings outside of the study group sessions. Participants began to think about applying the concepts learned through the study group in their future roles as teachers within their schools.

When I get into a school, why not get involved with a student equity group/club? If one exists, join. If there isn't one, start it!

I am excited to incorporate the dyad structure into my future classroom. I am thinking about "suitable" questions and topics to present to them. Also, I am excited to educate fellow teachers about equity in education (and lack thereof!).

We ended the session with the five-minute video, *It's In Every One Of Us*. Each participant received a copy of this tape to keep. This video portrayed the power and universality of our smiles and provided great closure: a sense that, as humans, we are all connected.

The smile is indeed the universal language! Thank you for the final five-minute film. That gave me hope because the smile reaches across the barriers and speakers' wisdom to every heart. I look forward to the fight, the good fight for equity.

This doesn't seem like the last session, and that must be why I'm not sad. I'm excited for more hard work because teaching equity is the pinnacle of fulfillment for me. I am saving my tears for the work and change that lay ahead of me, for now, I am building strength.

Summary

Because of this group, I am not the same person. The change is a positive one. My sensitivity level has grown toward those different from me and has also prepared me to be a better teacher toward my students. I am glad I had the experience before I begin to teach. I am looking forward to our future as equity leaders.

While the EMELI 4 team initially wondered whether we could present our 2-year experiences within a 15-hour study group, we were pleased that we had accomplished our goal and prepared the participants for leadership in equity. Fifteen hours had provided significant, engaged time for personal reflection and transformation. Through personal reflections that occurred in the dyads, small discussion groups, personal experience panels, support groups, and reflection sheets, individuals were able to trace and examine their own growth. They also left with the realization that the knowledge acquired could be transferred across their individual content areas, whether they are language, math, science, social studies, etc. They also agreed that meaningful communication, as a process, is the foremost step to resolution of our nation's dilemma. Significant curriculum reform will not happen until we, as a society, begin sincere efforts at communicating with each other.

The use of support groups demonstrated that meaningful communication can and does lead to enhanced awareness and understanding of challenging topics. The support groups continue to meet regularly today. Former students were asked to reflect about their empowerment as equity leaders and the impact they know they will have on children, as well as everyone around them. One noted:

> *Tonight was very important to me because I had the opportunity to try being a leader. I will say it was a little scary, but I enjoyed it greatly. I'm enjoying learning to be a better leader/facilitator. I especially like that I can still ask questions when I'm not sure what to do. This is my chance to grow into being a leader at my own pace.*

Working Toward Equity: Beginning the Conversation

Introduction

At the University of Northern Colorado (UNC), one faculty member from the Mathematical Sciences Department (a mathematician with experience in mathematics education reform) became a member of the EMELI 4 team and participated in the series of six sessions lasting from 1996-1998. This participation has, in turn, had a variety of impacts on the team member's department, professional development projects with teachers, pre-service teacher preparation, and the UNC RMTEC Scholars' Conference. The case of the UNC Scholars is described in this section to illustrate the process of addressing equity concerns in teacher education.

Need

The call for fostering diversity has become a mantra in education circles, so much so that it is possible to forget its origin. The unfortunate fact is that underrepresented minorities and females are even more underrepresented in mathematics and science than in other areas.

Programs that target members of underrepresented groups for special intervention may tacitly assume that underrepresentation is due to some defect in the members of that group, rather than to systematic practices and policies (whether explicit or implicit) that serve to exclude members of those groups. In short, working toward equity first requires an examination of the causes of inequity, namely racism, sexism and classism in society in general and education in particular. Colleges and college professors, as well as teachers and schools, need to examine not only curriculum, but pedagogy, faculty beliefs and expectations, admissions and advising practices, grading and assessment practices, financial aid and retention efforts, and other aspects of our work in order to determine how they support and perpetuate continuing inequities.

Process

One premise of the EMELI workshops is that children are hurt by experiencing institutionalized and personalized inequities in schools. The goal of EMELI is to create educational change by preparing educators to deal with equity issues in a positive, proactive, and constructive manner. The main issues focused on racism, classism and sexism, although many other issues arise and are considered. These issues are inherently difficult to deal with because they are inextricably bound up with personal experiences and emotions. In order for the issues to be addressed in a real and constructive manner, EMELI creates structures that serve to advance conversations that are both frank and supportive, such as the Constructivist Listening structures described earlier.

The first EMELI session, for example, is focused on racism. Educators spend the better part of four days exploring the personal and educational dimensions of this issue in an ethnically diverse group. Rather than merely examining curriculum or pedagogy, participants gain insight into how racism functions in their own experiences, in their own cultures and beliefs, and in their own educational institutions. These insights are vital in order to engage in an analysis of how inequities persist in spite of what appear to be significant efforts to eradicate them.

UNC Scholars

After participating in the EMELI sessions, the UNC team member was assigned to coordinate the scholarship program at the university. Scholarship recipients ("scholars") are required to participate in service activities related to the goals of RMTEC, particularly the diversity goals. They chose to conduct an annual conference for pre- and in-service teachers to fulfill this requirement. The conference focuses on reform in mathematics and science teaching and includes issues of diversity.

Scholars met biweekly throughout the academic year for a one-hour session, using materials developed by Julian Weissglass (1998) and utilized in EMELI. The goal was to help the scholars examine and clarify their own commitment to equity for all students, develop cross-racial and cross-gender alliances, and begin (or continue) the process of developing an anti-racist identity. The scholars were receptive to these activities, and indeed, the hoped-for alliances began to form as they worked together on organizing the conference.

As the scholars discussed equity issues and planned the conference, they decided that they would provide the presentation for the diversity/equity portion of the conference. They worked together to create some activities that would bring participants to a new way of considering equity issues. They selected readings, and made the presentation along with the Scholarship Coordinator.

Outcomes

Comments received from conference participants indicated that the scholars were indeed successful in their attempt to begin raising awareness among pre-service teachers:

One of the things I noticed about the dyads is that it caused me to pull things out from way down deep that I didn't know were there. When I was finished, I thought 'Wow, where did that come from?' The stories were excellent; especially the one about fear. . ..

The next step for me will be to attend more conferences on diversity and become more aware of the types of inequitable treatment students face. Then I can begin to recognize the problem with my students and begin to do something to change my behavior. I plan to encourage equity in my classes, not just in how I treat my students, but in how students treat each other as well.

I've noticed that equitable treatment for all groups of students is easier said than done. Of course in my teaching I have deliberately avoided the overt behavior of ridiculing any student and I enforce a 'no put downs' policy to create a safe environment. Questions are: What other things could I do to create a more cohesive group of learners? How can I identify students feeling marginalized?

. . .This really hit me hard. I can talk about different ways to deal with diverse students until I am blue in the face, but until I am actually forced to react to a real-life situation, it is a speculation. I want to go to different schools and see how the teachers there deal with everyday problems.

It seems clear that even in this short time (a one-hour presentation), participants began to clarify their understanding of and commitment to equitable treatment for all students.

Final Thoughts

The process of working toward equity is a multilayered one: it involves awareness, commitment, and then action (thoughtful reexamination of curriculum, practices and policies); those actions help create awareness in others. The movement from beginning awareness to clear action takes considerable time, but can be accomplished. The evidence of this case seems to support the idea that, with the right approach, it is not difficult to begin this process with pre-service mathematics and science teachers. The only question is whether we will commit the time and resources necessary to allow all pre-service teachers — and college and university faculty — to make this journey.

Conclusion

What lessons can higher education learn from RMTEC experiences in regard to diversity-related goals? First, it seems that structured experiences, in safe and caring environments, must be available on campuses if these conversations are to continue. Institutions of higher education cannot assume these discussions will occur without careful planning, which includes an infrastructure in which someone assures that professional development opportunities are available and supported by the administration. Second, institutional values and reward structures must support these activities, and faculty members need to be recognized for their participation in them. Last, the preparation of teachers needs to be recognized as a needed and valued area of higher education. How a faculty member teaches impacts society and becomes the environment that future teachers model in their classrooms. If we are indeed concerned about the quality of preparation of future teachers, then undergraduate curricula must be reformed to shift the emphasis from teaching to learning within the context of meeting the needs of diverse learners, and educating all learners to succeed in a multicultural society.

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7 Lecture? Group Work? Activities and Case Studies? A Search for Balance

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Hi. Are you still teaching that World Resources class? That was my favorite class. I really enjoyed all those activities.

World Resources? That class wore me out. I got very tired of all those activities and it was very depressing after awhile. We were always rushing to finish one activity in order to begin the next. I would prefer more lecture.

I am a hard working "A" student and I do not want my grade connected to people who don't do their share.

In retrospect the course makes sense, and what I learned is beginning to make sense. At the time, I didn't think I was learning anything.

—Unsolicited statements from students who took *World Resources* in previous semesters (Spring, 1999)

Geography 140, World Resources, is an activity based course that includes active case studies and simulations, as well as passive research projects. Students work in a different group for each activity and make presentations on each resource topic. During fall 1998 and spring 1999 semesters, RMTEC supported continued revision and evaluation of the course through two grants that are discussed in this chapter.

Background

Geography 140, World Resources, is a General Studies course that fulfills a science requirement. Approximately 5 years ago, I began revising the lecture based course to include some activities and case studies because the lecture based course seemed to lack application of materials and led to information overload. The students were not involved. In conducting research on active learning and the use of case studies, I came across this quote from Alfred North Whitehead:

What the faculty have to cultivate is activity in the presence of knowledge. What the students have to learn is activity in the presence of knowledge. [I reject] the doctrine that students should first learn passively, and then, having learned, apply knowledge . . .. In the process of learning there should be present. . .a subordinate activity of application. In fact, the applications are part of the knowledge. For the very meaning of the things known is wrapped up in relationships beyond themselves. Thus unapplied knowledge is knowledge shorn of its meaning.

Alfred North Whitehead, *Essays in Science and Philosophy* (New York: Philosophical Library, Inc., 1947) 218-219, quoted in C. Roland Christensen, with Abby J. Hansen, *Teaching and the Case Method* (Boston: Harvard Business School, 1987), 16.

Whitehead's statement provides the background philosophy for the revision of the course to an active learning approach based on application of information. The revisions are also based on group organization and peer instruction.

Four years ago, a team of three part-time faculty (Catherine Dwyer, Sharon Gabel, and Jeff Miller) and three students volunteered to meet with me over a period of six months to discuss course content, student involvement, and the direction the course should take. We restructured the course and agreed that the faculty would all use the same approach and the same materials. I had developed a number of activities which we reviewed, evaluated, modified and incorporated. The students chose one activity, a

World Bank Hearing, to redevelop themselves. Since that time, the course has continued to evolve. Each semester, the students have been asked which activities they liked the best, which contributed to the greatest learning, and which ones they did not like. They also have been asked to explain their answers. The course has been reviewed and modified each semester.

Because they liked the course, several students have volunteered each semester to assist during the following semester; some have received credit and some have not. Student volunteers have included both Teacher Education students who were interested in classroom organization and group learning activities, and Land Use students who were more interested in how concepts and information were presented in the activities. During the summer of 1998, I worked with a Teacher Education student who developed an activity on energy and a Land Use Student who began to develop an activity on mining. These advanced students were encouraged to take responsibility for presenting activities throughout the semester.

An additional challenge was the textbook. When we changed the format of the course we shifted from a regular text to a data book with a short written section on each resource. Students also use a *World Fact Book* which provides general information on each country. There are many concepts and terms and it is up to the instructor to integrate content and provide definitions for the terms. There was a recognized need to develop a glossary and a unified approach.

All of these variables led to a proposal to RMTEC to support the Land Use student to conduct extensive research to finish developing the mining activity on the Climax Mine in Leadville, Colorado; and release time for me to develop a glossary, reformat all the activities in a single format, and continue restructuring the course during fall 1998. It also led to a proposal to evaluate the two new activities developed by the students for two semesters and obtain more student responses to the course.

RMTEC Project – Fall 1998

With the RMTEC focus on Earth Science and a skilled and knowledgeable Teacher-in-Residence, Steve Williams, to support the project, I requested one-fourth release time to reorganize all of the activities into a consolidated format that would include a brief overview, key terms and concepts, measurable objectives, general information based on roles or perspectives, and general information. A stipend was also included for the student to continue data gathering on the Climax Mine in Leadville.

It was arranged that Steve would teach two sections of GEG 140 and Betsy Forrest, a part-time faculty member, would teach one. This was an excellent arrangement, as Steve and I touched base nearly every day and I obtained feedback from Betsy once a week. Each activity was revised and reformatted, presented to the students and immediately revised again based on faculty observations and student reactions. Steve expanded the grading rubric for the writing requirement and developed a rubric for the oral presentations. One activity, Ecological Footprint, was expanded from an optional activity to a requirement. Steve also introduced a Concept Mapping activity, which will be incorporated into the course as a requirement. I developed a glossary which proved to be very helpful.

The two activities developed by the students were presented in all three sections of the course and it seemed that student responses varied based on perceived amount of work, level of involvement, and type of class presentation required. With three faculty members cooperating on the project we have been able to address issues beyond the original scope of the project and we have made a great deal of progress. At the end of the fall semester the following activities were included in the course:

1. **Bomon** is a simulation that addresses the relationships between resources, boundaries, politics, and economic development. Students represent groups in a former colonial area which is gaining autonomy and argue for particular boundary alignments. This was adapted from another source.

2. **Population** is addressed through a series of short research activities designed to apply concepts relating population growth, distribution, and density to resources.
3. Group research on clusters of countries experiencing different rates of **deforestation** engages students in the relationships between population and development.
4. The organizing question for the section on **food and agriculture** addresses the relationships between the physical environment, population growth, patterns of urbanization, level of development, and food production.
5. Global **water resources** are addressed through two simulations: impacts of the diversion of water from the **Aral Sea** in Uzbekistan and Kazakhstan and the damming of the **Euphrates River,** which impacts Turkey, Syria and Iraq.
6. **Air quality** is analyzed through a process of developing a questionnaire which is tested to ensure that students are obtaining useful answers. When students are satisfied, they administer the questionnaire and evaluate the responses.
7. Issues related to **marine resources** are discussed in general. The activity is based on data collected through The Great Beach Clean-Up. Data is evaluated and compared for different regions.
8. The two new activities are for the **Energy and Minerals** section. Energy is addressed through a simulation based on the dynamics students learned in the Bomon activity. Groups represent countries with specific interests in oil development in the Caspian Sea region. Issues related to mineral development are presented through a case study of a molybdenum mine in Leadville, Colorado. Students also represent the stakeholders.
9. In the **Ecological Footprint** activity, students are asked to keep a record of different types of resources they use over a specified period of time. The data is used to determine how much land is required for each student's lifestyle and to relate this lifestyle to other resource issues for the future.

Two activities serve as final integrators for the course:

1. The **World Bank simulation**, in which students research selected developing countries, asks students to apply what they have learned and request (or not request) funding for development projects from the World Bank.
2. **Concept Mapping**, introduced by Steve at the end of fall semester, asks students to identify the key concepts from each activity and link them conceptually and graphically.

At the present time, all students are required to participate in all activities. As part of the evaluation of student responses during spring semester consideration will be given to requiring fewer activities and creating options.

RMTEC Project— Spring 1999

During the spring semester, the proposed task was to continue evaluating the two new activities in Energy and Mineral resources as well as the overall course. Student responses to activities were noted during the semester in addition to the specific questions about the new activities. The outcomes are interesting and thought provoking. A review of student comments will be followed by our ideas for reorganizing the course.

Should There Be More Lecture and Fewer Activities?

Four issues emerged related to the debate of lecture vs. activities including the amount of work, amount of lecture, perception of learning, and grades. Many students felt that the amount of work increased in the activities based format. Lectures and activities were perceived in dichotomous ways: lectures were easier, while activities were more fun. Lectures require no active involvement. If you miss class someone will give you their notes, but there are few notes for the activities. . .you have to be there. A question was also raised about whether or not fun equated with non-learning. Some comments were:

I was happy not to have a class with a lot of lecture.

I believe we would have gotten more out of having more lectures. It seems like there is too much information to cover and I believe it would have been more beneficial for us to have fewer topics, but expand on them more.

Should the Number and Type of Activities Be Reduced?

The involvement in so many activities wore everyone out, students as well as instructors. There was agreement that there should be fewer activities with more time available for students to work together and prepare presentations. Activities are time consuming. It was also noted that different students liked different activities and by eliminating some activities it reduced options. There was also a request for fewer activities with lectures inserted to address the time issue, to allow more time for class discussion and to provide more linkage between topics and concepts.

Is There Enough Variation in the Type of Activities?

A trend appeared that separated student responses related to the type of activity. Few students identified the passive activities as favorites, although they did identify the food and agriculture and beach cleanup as meaningful.

Should There Be Tests Rather Than Writing and Participation?

Despite the request for fewer activities and more lecture, the response to this question was 100 percent in favor of the activities and written evaluations rather than tests. On the other hand, some students viewed participation as the outcome rather than the written papers. They took responsibility for the presentations, but did not turn in their papers. This led to the next set of observations.

Is There Any Difference in Response by Different Types of Students?

It was difficult to generalize about this question. MSCD is a modified admissions college with an average student age of 27, and a nearly equal division between male and female and day and night students. The character of each class is different each semester and so are the responses. It could be observed in one section that students who prefer the lecture method don't do as well with activities; however, in another section this would not hold true. The same could be said about age, gender, and zeal to achieve. In some cases, lower achievers found this style appealing while others did not want the responsibility of determining when to get the work done. One very good student flatly stated that he only did well in a lecture format and didn't really try in the activities. Memory served him better than application.

What Is Your Response to Group Work?

This question probably garnered the greatest response. The organization of the entire class is based on group work. Students are assigned to different groups for each assignment with only one enduring group for the semester, that of the World Bank project. Students are graded individually rather than as a group and the groups are not required to evaluate the individual members. Many students are aggravated by group members who don't contribute their share, who don't show up for a presentation, and/or who make poor presentations. Some students develop a reputation as poor group members which carries throughout the semester. One student wrote an extensive letter to the professor addressing her dissatisfaction with the group approach. An excerpt follows:

> *With the exception of the first activity, my experiences of group learning in this class have been extremely poor. . .students have not been accountable.*

This student also observed that if the students were able to form their own groups based on accountability the course would have been better. There was extensive concern expressed for her own serious desire to learn.

What Do the Student Assistants Gain From This Experience?

Without exception, the student assistants indicate that their participation has been an exceptional and positive experience. They all learn many of the same things, but their verbalization is different. The Teacher Education students learn the pros and cons of group work, the use of different types of activities and different ways to present written assignments. They gain experience in answering questions, and synthesizing, and become comfortable with varying roles of the teacher before going out for their school experiences. The Land Use students have indicated that they have learned more the second time around and learned from answering questions and making connections.

What Is Your Reaction to the Information in the Syllabus vs. in the Activity Assignments?

There is too much information in the syllabus. The key concepts and terms are included in the activities and just confuse the syllabus.

How Do You View the Role of the Instructor vs. the Role of the Student?

For many students it takes time to shift perceptions about who is responsible for learning. For many students the concept of peer teaching is foreign and unacceptable. If the professor is not up in front pontificating he or she is not living up to expectations and responsibilities. As one student indicated, *I paid my money and it is the professor's responsibility to teach me.* The concept of how we learn and who is responsible for learning may not be recognized and/or is confusing. There are students who indicated that their perceptions changed during the semester. For others, it may occur over time, or it may never change.

From the faculty perspective, the activity approach is a great deal of work. There is a significant increase in the amount of time spent copying materials as well as interacting with students. Students who are worried about the different approach tend to drop into the office more often. Also, as students recognize that they are viewed differently they tend to drop in to discuss the class, their majors, future goals and personal issues. The faculty member needs to be prepared to meet these demands.

Which Approach to Energy and Minerals Did You Like the Most?

Student responses to these activities reflect many of the statements reported above. Some students were able to find a fit, while others continued to separate the method of presentation and learning. Overall, students were more positive about the activity in which they participated and tended to feel that since they contributed they learned more. This was an interesting observation and would seem to indicate that there is still a need for integration. A majority of students preferred a presentation with the goal of gaining approval, with a decision at the end of the presentation, rather than simply presenting information. Somehow, this process helped students put the issue into perspective. The following are some student comments:

A lot of learning takes place during my reflection on the lesson. For this reason I like having a board give a decision.

I felt that I wasn't just informing the class, but I was fighting for somebody's opinion. Therefore, I had to know what I was talking about and that involved learning the material.

Presentation with decision is more realistic.

Many students made comments about reality vs. role-playing. Reality seemed to be viewed as more facts and role playing to get information across was still questionable.

The Climax Mine activity had a lot to do with the State of Colorado and it had to do with money, population, etc.

. . . I learned more from this (Climax) activity because the information was easier to take in since it was so close to home.

I learned the most from the Climax Mine exercise. The way it ended didn't allow for conclusion. You walked away from it thinking about the issues. It was more realistic than the Caspian Sea because it was based on data not role playing.

Vs. . .having a decision gives closure.

I liked the approach of the Climax Mine, but I learned more from the Caspian Sea.

. . .It was an activity that affected countries outside the U.S. and kept me listening to find out what was going on.

The format of the mine activity was more real. . .It was due to the format used.

The overwhelming key to student responses was involvement. It should be noted that there was one variable for these activities that was not included in the others during the semester and this was that the students were told in advance that they would be asked to evaluate the two activities. It seemed to help focus their research, presentations and responses.

Where Do We Go From Here?

Based on our observations and student responses, we have decided to take the following action:

1. Streamline the syllabus as much as possible. The grading rubrics will be included in the syllabus, but key concepts and terms will be restricted to the activities.
2. The number of activities required of all students will be reduced, allowing more time for group work and discussion. Also, activities will be divided according to level of involvement. There will be fewer activities required that are very involved, allowing more time for group work and classroom discussion. Some activities will be reoriented to a lecture format and the order will be changed to intersperse high and low involvement. How students will be assigned to groups is undecided, as is the issue of group evaluations.

a. **Lecture with Classroom Data Sheets (no group reports)**
Population
Deforestation
Food and Agriculture
Great Beach Cleanup
Air Quality

b. **Required Activities for All Students**
Bomon
Aral Sea or Damming Euphrates
World Bank
Caspian Sea or Climax Mine
Ecological Footprint

3. The concept mapping activity was added at the end of the fall semester. All students participated in creating the maps, but not all got the message. Selected maps have been on display on the Science Building and have generated a great deal of discussion. The maps have been addressed throughout the spring semester so that students have a better understanding of what is expected and what a concept map really is. They will be evaluated in mid-May. Steve Williams has created a web site where the best maps can be accessed and discussed. It is anticipated that the concept maps will emerge as the integrative thread for the course. The website can be accessed as follows: http://www.dcsd.k12co.us/secondary/dchs/index.html. Then select the following: departments, science, and concept maps.

In conclusion, this type of activity-based course requires change on the part of both faculty and students. In order for the course to be successful, the faculty has to buy into the basic premise of how students learn, and the course format. For students, the activity-based approach to teaching and learning may be like moss. . .it grows over time and creeps up to surprise you.

The following is a quote from a student in Betsy Forrest's class during the fall semester:

I am a hard working, experienced adult student used to working on my own. . .and I am successful. I hated group work. I hated my group. I hated the class. I requested to form my own group, but the instructor said no. I had to have the class and could not quit.

When we did Bomon I had to stand up in front of the class with two young guys who did not seem to contribute anything and they had no understanding of environmental issues. They called themselves the Beaver Lovers. Just imagine!

I put my embarrassment down and decided to go with the flow. Much to my surprise we were so convincing that we obtained all of our requests.

It took awhile for me to relax. But by the end of the semester, I was able to participate differently in the groups. What I really want to tell you is that without this class I would never have succeeded in my junior level planning class. All the work for the semester was assigned in groups. The World Resources class made me understand the process in addition to the issues. . .and I got an "A" in the advanced class.

8 The Genesis of Change: Teacher Preparation to Promote Implementation of Multicultural Math

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Math that includes non-western history and modes of thought. . .
Mathematical thinking/developments of other cultures. . .
Math where learning is not limited because of race, sex, cultural differences. . .

— Teacher candidate explanations of multicultural math

The Mayan calendar and pyramids, teen smoking statistics, election returns in South Africa, international flag designs—what relationship can or should these have to curriculum practice in secondary school math? Teacher candidates emerging from RMTEC classes in teacher education that focus on teaching responsively to an increasingly diverse student population can tell us. These are some of the multicultural math topics of lessons prepared as part of the reform curriculum in teacher preparation.

RMTEC math teacher candidates have begun to challenge traditional assumptions and provide answers to traditional questions framed by more experienced peers who may say, *Math is math! Right? What do you mean multicultural mathematics? How can the study of numbers, their relationships and applications, be different for different people or in different environments?* Teacher candidates may respond that math is an accumulation of contributions made by many races, cultures, and ethnically diverse people. One teacher candidate, for example, explained multicultural math as *math that includes non-western history and modes of thought.* Another said that multicultural math is *mathematical thinking/developments of other cultures.* They may respond that the study of numbers should build on the life histories and cultural resources of the particular students in math classes. Again, a teacher candidate described multicultural math as *math where learning is not limited because of race, sex, cultural differences. . .* Generally, math teachers emerging from the Metropolitan State College of Denver (MSCD) program state their commitment to promote the success of students from diverse backgrounds. They want classes in which, . . .*all students are successful and feel they are valued in the math classroom*, as Stacey Fillhart, middle school math teacher and RMTEC graduate wrote.

Purpose of Study

This case study describes reforms that support math teacher candidates in their development and implementation of multicultural math lessons and equitable teaching practices during a two-semester sequence in their pre-service teacher preparation. How do teacher candidates respond to the diversity of their class, design relevant curriculum, and assess the effects of instruction on their students? It examines issues and constraints, levels of current use, levels of desired future use, and what prospective and novice teachers need to move forward.

We have learned a great deal. With each successive new class of RMTEC student teachers, their awareness, commitment, and implementation of multicultural mathematics becomes greater. With each successive new class, our teacher education practices are further refined and developed to meet more teacher candidates' needs.

Method

For the teacher preparation program to better support teacher candidates' development of knowledge, commitment, and action leading to multicultural mathematics, many stages and categories of change have been necessary. These changes have been made in program structure, resources, curriculum, inquiry, faculty behaviors, and enrichment options available to teacher candidates. The structure and resources for change initiated the process of reform. In brief, essential structural changes included higher levels of communication and teaming. This followed from early restructuring linking the math methods and education methods courses and field experience. Math methods faculty learned more about how education methods courses functioned; education methods faculty learned more about how math courses functioned. Areas of tension as well as areas of mutual agreement surfaced. The most positive impact was the establishment of a requirement for courses to be taken concurrently. That requirement enabled us to sustain the structure needed for a shared field experience, a practicum that is positioned in the education department but serves both math and education methods. Both departments participate in placement decisions. Teacher candidates complete field reports and assignments for both methods courses based on the same school placement.

A second structural change impacted student teaching. The "math cohort" was developed and a math content specialist was hired as student teaching supervisor. Previously, math teacher candidates were supervised during student teaching by college faculty who may not have had expertise in math. Now, all math student teachers are supervised by the same college supervisor who is a math content specialist. Seminars that used to include student teachers of all content areas now target math student teachers only. This structure enabled us to make thoughtful decisions about change, and to be assured that changes implemented would impact all math student teachers.

A final structural change involved the collaboration of the college supervisor of math student teachers with both math and education methods instructors. Over the course of the grant, the college supervisor has communicated regularly with methods faculty in both departments, attended the math methods class, and collaborated with education faculty on the development of the multicultural math web page. Both education and math methods faculty have visited student teachers with the college supervisor, participated in seminars, and collaborated in inquiry and reflection to improve the program.

Resources supported the purchase of multicultural math books, manipulative kits provided to all math student teachers, and faculty development in multicultural education for the math content specialist. In addition, resources for the multicultural math web page and the Equity Leadership Study Group, a one credit hour elective (15 contact hours) focusing on socio-psychological dimensions of learning and schooling, and addressing issues of race, sex, and class as they affect student learning, enabled us to offer many math teacher candidates the preparation to initiate change. (The Equity Leadership Study Group is described in greater detail in Chapter 6: Meeting the Challenges of Diversity in a Context of Reform.) And finally, resources supported our ongoing inquiry through formative evaluation data, surveys, focus groups, and undergraduate researchers, leading us to ongoing reflection and change.

While the structure and resources for change were essential prerequisites, the other categories of change — in curriculum, faculty behaviors, and enrichment options available to teacher candidates — occurred within the context of the three courses described herein.

EDS 3210 –Curriculum and Management in the Secondary Classroom

Math and education faculty collaborated in planning "multicultural" reforms of a pre-student teaching curriculum and management course (EDS 3210) and a related field experience (EDS 3220) during one semester, followed by student teaching and seminar (EDS 4290) the next semester. In the first semester of the sequence, the faculty member changed the curriculum to integrate global education content and standards, to increase the variety of lesson designs presented (including both cooperative learning and learning cycle), to provide math content standards to all math teacher candidates, and to require that all lessons and units address math content standards. Thus, teacher candidates design multicultural math lessons that address math standards using a variety of models of lesson designs. They teach the lessons they design to peers in micro-teaching groups, receive feedback, and write reflections on the lesson and possible future directions. The faculty member provides feedback on each of these formative, microteaching lessons.

Later, teacher candidates plan and present global, interdisciplinary team teaching lessons to peers who role play middle or high school learners. This activity promotes the use of math for problem solving, communication, reasoning, and making connections. It provides students opportunities to . . *.explore relationships among mathematics and the disciplines it serves: the physical and life sciences, the social sciences, and the humanities,* as National Council of Teachers of Mathematics and global education standards recommend.

A second level of change within EDS 3210 involves change in faculty behaviors. Now, in addition to requiring teacher candidates to integrate multicultural content, the teacher education faculty integrates more multicultural teacher education content, activities, and resources. To illustrate, case studies of students of color in secondary schools from Sonia Nieto's *Affirming Diversity* (1992) are used as the focus of a jigsaw activity that gives teacher candidates a clearer sense of others' ethnic and cultural identities. Both the content of the lesson and its jigsaw structure model dimensions of multicultural education. Further, faculty now offer relevant options through which teacher candidates can develop their multicultural teaching skills. For example, during 1998-99 approximately 30 teacher candidates participated in the Equity Leadership Study Group.

A final behavior that is changing is that an explicit "in progress" definition of multicultural education/multicultural math is articulated each semester, in a more comprehensive form each time. This both reflects the college faculty's growing awareness and serves as a guide to greater depth in multicultural education implementation.

The figure that follows displays six dimensions of teaching and learning identified by Weissglass (1992). The authors added one more dimension to indicate "outside of class learning" in keeping with James Banks' (1994) idea that multicultural education also encompasses the surrounding school culture and community context. Further, the authors sorted teacher behaviors that address diversity into the seven categories.

Figure: Key Teaching/Learning Dimensions

1) Socio-psychological dimension

The multicultural math teacher. . .

✦Promotes supportive student attitudes (promotes students' rights and respect for human differences; helps students develop positive racial attitudes/values).

✦Models supportive teacher attitudes (models self examination; teaches about the dynamics of prejudice and racism and how to deal with them; believes all students can learn; critically analyzes oppression and power relationships to understand racism, sexism and classism and discrimination against the disabled, young, and aged).

✦Develops a sense of classroom community.

✦Interacts with understanding and responsiveness to people of color and women.

2) Individual needs dimensions

The multicultural math teacher. . .

✦Connects content and methods to the students' knowledge and the real world.

✦Places students at center of the teaching and learning process.

✦Links math to physical context of learners' experiences.

3) Socio-cultural dimension

The multicultural math teacher. . .

✦Helps students understand how knowledge is created and influenced by racial, ethnic, and social class positions of individuals and groups.

✦Integrates multicultural and global materials and models into math content (ethnomathematics — math embedded in different cultures' daily life).

✦Uses examples, data, information from a variety of cultures and groups to illustrate key concepts, principles, generalizations, and theories.

✦Teaches content that provides a clear sense of other's ethnic and cultural identities.

✦Delivers content or sets up activities that provide opportunities for success to second language learners.

4) Transmitting knowledge dimension

The multicultural math teacher. . .

✦Teaches content that reflects humanity's accumulated understandings.

✦Integrates content with the life histories and cultural resources that reflect students' cultural memberships.

5) Mathematical power and constructivism dimension

The multicultural math teacher. . .

✦Uses varied methods that address varied styles and lead to purposeful activities.

✦Focuses on use of math for sense making.

✦Reflects on teaching and learning mathematics, processes math understanding in language.

✦Models equitable pedagogy—that facilitates academic achievement of diverse students.

Key Teaching/Learning Dimensions (Cont'd.)

6) Critical pedagogy dimension

The multicultural math teacher. . .

✦Creates lessons that critique society in the interest of social justice and equity.

✦Designs instruction with "social justice" actions/ extensions outside of class.

✦Facilitates students' use of math as a tool to analyze issues facing society.

✦Designs instruction that can lead to collective social action to promote social justice.

7) Outside-of-class learning dimension

The multicultural math teacher. . .

✦Works with parents.

✦Works toward institutional change to restructure the school so that students from diverse groups experience educational equality and cultural empowerment.

✦Develops knowledge and understanding of community.

(Created after semesters of teaching, reflecting, holding focus groups, and examining multicultural instruction models of Banks 1994, Gollnick & Chin (1994), Zeichner (1992), Weissglass (1992) "CMC ComMuniCator" Vol 18#1, and the RMTEC diversity model.)

EDS 3220—Field Experience in a Secondary Classroom

The urban setting at MSCD guarantees that students work with ethnically and racially diverse classes in at least one of two field experiences. During these experiences, teacher candidates experience diverse students, faculty, parents, and communities first-hand. They have the opportunity to learn how schools are structured and how that structure either supports or blocks equity in math classes. In surveys and focus groups, many teacher candidates describe the field experience as most valuable in their multicultural education, particularly if their background experiences lacked racial, ethnic, and social class diversity. The field experience has changed in certain ways to promote multicultural education during the RMTEC grant. In weekly field experience seminars, structures for communication on equity are introduced to open dialog about racism, sexism, and classism and to promote reflection on the field experience. Teachers who are dedicated to math reform are sought as supervising teachers and math and education faculty collaborate on placements. More and more placements are in high schools with Interactive Math Programs and other reform initiatives.

Evaluation forms for field experience include assessment of teacher candidates' effectiveness in teaching to diversity.

Still, ongoing research about the growth of multicultural understandings among teacher candidates suggests that the field experience is an area for needed growth and further reform. We need to work on placements, communication, faculty development for supervising teachers, and more structuring of field experience. To begin with, more intensive dialog is needed between math and education faculty at MSCD on the specific issue of multicultural education in field experience. Ideal placements are with supervising teachers who model culturally sensitive teaching, cooperative learning, learning cycle, problem-based lessons, rubrics for assessment, and teaching to math content standards. Since the number of teachers who meet this description is limited, a successful future for this effort will have to involve shared faculty development.

In focus groups and field reports, teacher candidates sometimes express disappointment about placements in which supervising teachers demonstrate racism or sexism, or in which school-wide policies result in unequal representation of different races, ethnicities, or genders in advanced math classes. These problems occur in both traditional and reform based classes. It is clear that we need to locate, work with, and place students with math teachers who believe all students can learn math and who model multicultural math content and pedagogy. A valuable next step may be to provide Equity Leadership Study Groups for all supervising teachers who work with teacher candidates, both in field experience and in student teaching.

One improvement ongoing in spring 1999 is a more structured plan for field experience, one which can eventually specify that teacher candidates should have the opportunity to teach and receive feedback from students on a multicultural lesson in their content area.

EDS 4290—Student Teaching and Seminar

In the second semester of the two-semester sequence, the multicultural theme and emphasis are integrated throughout the curriculum through faculty modeling and student teacher requirements. The college supervisor expects student teachers' lessons to show that math reflects humanity's accumulated understandings and that diverse students' needs are equitably addressed. Both college supervisor and student teachers use varied methods, link math to the physical context of the learners' experience, focus on the use of math for sense making, discuss ways to interact equitably with students who are often under-served in math classes, and reflect on practice.

The math content specialist supervises a cohort of math student teachers in observations, assignments, and seminars. Math student teachers are required to locate, adapt, or develop one multicultural math lesson and share it with other student teachers in seminar. They are asked to teach these lessons as part of their student teaching. In addition to submitting a multicultural lesson plan, student teachers write metaphors on teaching and learning, a letter to a prospective student teacher, and a lesson plan using either technology or a manipulative. When student teachers present the aforementioned items at seminar, there is always a discussion about how inclusive the metaphors, letters, or lessons are. The faculty member models a wide variety of reform-based approaches to math, provides leadership and resources for integrating multicultural math, and uses some techniques to provide student teachers the opportunity to reflect on their attitudes and beliefs around learning mathematics. Student teachers too must present a wide array of lesson approaches during student teaching, including some mathematics that is culturally specific. They also are expected to provide opportunities for students to reflect on their own learning. Narrative feedback following observations refocuses student teachers on their progress in meeting these requirements. All student teachers keep a journal of the entire student teaching experience and present portfolios during seminars, with artifacts representing all areas of the professional teacher standards, including diversity.

Teacher candidates who want advanced learning in multicultural math may elect to participate in the Equity Leadership Study Group, collaborative research on multicultural education with faculty, and/or multicultural math web page development.

Inquiring Into Practice/Changes in Teacher Candidates

The previous section described methods we use to promote implementation of multicultural mathematics. This section describes ways we inquire into our practice, focusing on teacher candidates' levels of awareness, commitment, action, and competence in multicultural mathematics.

From a variety of data sources, including surveys, interviews, observations and teacher candidates' multicultural lessons, we know that emerging math teachers want more information about multicultural math. Seventeen prospective and novice math teachers responded (summer 1998 and spring 1999) to a "multicultural mathematics survey" distributed to RMTEC prospective and novice teachers at MSCD. One of the questions was, *Would you like more information about multicultural mathematics?* Sixteen replied yes. Only one student said no.

Surveys indicate novice teachers' current use of multicultural math is lower than they would like. Only three of the nine responding RMTEC graduates who hold jobs as beginning mathematics teachers reported that they had taught a multicultural lesson they developed in the teacher preparation program, or another multicultural lesson, since they had begun teaching.

The constraints preventing teachers from implementing multicultural math were investigated. In interviews during the summer of 1998, many participants indicated that they valued multicultural math and wanted more ideas and teacher-ready lessons. One RMTEC graduate had been able to attend an excellent multicultural education in-service through Jefferson County Schools, focusing on individual needs and the socio-psychological dimensions of learning. He was enthusiastic about the prospect of receiving resources from other teachers and through RMTEC and he received Claudia Zaslavsky's multicultural math resource book (1993) for participating in the interview. Still, like many beginning teachers, he reported that he focused most of his attention on surviving his early teaching experiences. In his first two semesters he had never been evaluated by a peer or principal, nor had he received any mentoring. The day-to-day demands of planning activities relevant to high school students were such that multicultural content was pushed into the background.

Other data suggest that emerging math teachers are more than just open to multicultural math. In surveys and student teaching seminar discussions, prospective and novice math teachers consistently state that they want to address the needs of students coming from different cultures, students of color and young women who are not achieving in math class. The evolving concept of multicultural math may provide some options. It appears that many teachers have difficulty incorporating culturally specific content into their lessons, especially in the first year of teaching. Some current student teachers and faculty have discussed the idea that the process of educating a multicultural classroom is at least as important as the content used. It will be interesting to see how such ideas translate into practice.

There is also evidence that math student teachers are developing increased skills in designing multicultural math lessons. Of the 62 multicultural mathematics lesson plans that have been submitted by teacher candidates during the past four and one-half years, more and more of them are original, contain assessments, and specify the standards connections. Two-thirds of them are historical in nature. The other third are real life math applications, mathematics lessons exploring social and global issues, math built from a shared in-class experience using technology or manipulatives, or a deliberate use of a culturally sensitive approach to presenting a specific math concept.

While teacher candidates show openness, concern, and growing skill in multicultural math, the transition to implementation is hard for new math teachers. According to observation data and conferences with student teachers, the level of multicultural math content student teachers see implemented during student teaching is limited. When examining textbooks for dimensions of multicultural mathematics, mathematics student teachers notice that little snippets of historical facts are often included in the margins of the pages, but student teachers comment that these are rarely included in the teachers' daily lesson. One student teacher said that she thought the historical facts were treated as an extra bit of information, not particularly relevant or important to the mathematical concepts.

Investigations Lead to New Questions and Answers

One change we wanted to see was a higher number of teacher candidates implementing multicultural lessons, in particular, the ones they wrote. It is ironic to note that at schools using a more integrated curriculum, which are priority placements because of their commitment to math reform, teacher candidates have difficulty getting opportunities to teach their original multicultural math lessons. They may be perceived as a multicultural "add on" in an already "transformed" curriculum that infuses multicultural dimensions throughout. This may be a problem of definition. Student teachers' lessons focusing on the "socio-cultural" dimension don't seem to fit, yet integrated classes may already incorporate other key multicultural dimensions, such as "individual needs," and "mathematical power and constructivism." Sometimes student teachers say the integrated program accommodates multicultural learners in other ways. Others note the problem seems to be finding the appropriate time and place in the curriculum to teach an original lesson with a non-western cultural focus. Perhaps integrated programs need to incorporate more of a global dimension to meet the needs of diverse students. In any case, student teachers still find it easier and more possible to teach their multicultural lesson in schools with a traditional curriculum.

Regardless of the fact that teacher candidates know the danger of low expectations for students' learning, translating this awareness into action is difficult. Student teachers are aware of the make-up of their classrooms. That is, they know the ratio of boys to girls, if there are students of color and if so how many, and if some of their students' primary language is different from English. Acting on their awareness of the composition of their classrooms to make the math lesson more inclusive is difficult for student teachers. Even though they know about dangers of gender inequity, in a number of student teachers' classes, boys are still called on more often than girls are and boys volunteer more often than girls do. Of the 35 observations made by the college supervisor this spring semester, about one-half of them resulted in suggestions and recommendations to include more girls and students of color in the discussions and presentations. One student teacher said, *I know that I expect less from students of color and I think I do this because I am afraid that they will not know the appropriate answer and I do not want to embarrass them.* Also, . . .*because they are absent lots of the time they probably will not know what is going on.* Student teachers need to develop intercultural communication skills and confront both their own biases and other barriers they see as impeding students' learning. While over time student teachers are improving in holding high expectations for all students and insisting that all students participate, there is a continuing need for deliberate vigilance in this area.

Looking back at the multicultural mathematics lesson plans, observations made, discussions both in seminars and through debriefing sessions, videos of lessons taught, written reflections, regular inclusion of technology and manipulatives and a growing awareness of diversity issues by student teachers, one is cognizant of in-roads being made for a more equitable classroom. However, further progress is needed. In a recently visited classroom of high-level mathematics, *Advanced Placement Calculus*, there were eleven students — nine boys and two girls. During the 48-minute period, one girl spoke once and the other girl said nothing; the one minority student did not offer anything either, nor was he called on. When this was brought to the attention of the student teacher, he seemed surprised. He thought every student was actively participating. Increasing awareness and knowledge, and finally being committed to the idea that all students can be successful, are requirements for all of our mathematics teachers in a multicultural society. Student teachers need more work in the "socio-psychological" dimension of multicultural math. They need more skills to interact with understanding and responsiveness to people of color and women. Enrichment options like the Equity Leadership Study Group should, perhaps, become requirements for teachers emerging from programs committed to multicultural mathematics and equity.

Case Within a Case: One Teacher Candidate's Growth in Multicultural Math

In one lesson developed and taught in EDS 3210, teacher candidate Jeff Buck explores social and global issues. He focuses on the role of mathematics in the electoral system of South Africa. His math lesson integrates South African materials and social realities. He shows how math is embedded in daily life, and uses examples, data, and information from South Africa to illustrate key concepts about percentage and proportion as they relate to real life concerns of politics and human justice. His lesson facilitates students' use of math as a tool to analyze issues facing society. He makes students in American schools more aware of global dilemmas and challenges.

Mr. Buck is one of the students who has taken advantage of the option to participate as co-researcher with faculty to investigate multicultural math and equity. Through this activity, he is exploring the "critical pedagogy" dimension of multicultural math. Not only did Mr. Buck participate in the Equity Leadership Study Group, he also collaborated with Professors Ruggles and Taylor by providing a mini-case study describing his implementation of a multicultural lesson during student teaching. This case study follows in its entirety and describes Mr. Buck's math class student population, his lesson, and his students' evaluation of the lesson.

Mini-Case Study

Assessment of class diversity: South High School has an English Language Acquisition (ELA) program. As a result, classes are unusually diverse. In the two algebra classes I work with there are students from eastern Europe, the Middle East, Africa, Asia, South America, and, of course, the United States. Gender diversity is more typical of an advanced algebra class. There are 32 males and 18 females between the two classes.

The cultural diversity of these classes presents some unique opportunities. For example, we had impromptu demonstrations of different pencil and paper algorithms for division from several students and talked about how they are similar to and different from the long division algorithm taught in the U.S. This was particularly helpful to students who went to elementary school in other countries. Some of them were having difficulty understanding long division with polynomials because they had learned to divide differently.

Synopsis of multicultural lesson: Students were given a short list of Internet web sites related to mathematics. Included were: Texas Instruments' graphing calculator home page, "The History of Mathematics" (which includes material from Japan, China, India, the Arab world, and South America in addition to western math history), "Women in Mathematics," "Mathematicians of the African Diaspora," and "The Math Forum" (which includes information and lessons on specific topics plus links to pages for many subjects related to mathematics). Students were asked to hit the page of their choice to see what they found. After exploring the web site and one or more of its links, students were asked to respond in writing to the following questions: What page did you visit? What did you find there? Was the site well organized and easy to use? Did you like the site? How might this page be useful to you in the future? What did you think of the activity? Were expectations and instructions clear?

<u>Evaluation:</u> Students were unusually focused on the task during class. Everyone was able to find information of interest and students' written responses were very positive. One wrote that she would share "Mathematicians of the African Diaspora" with her family. Another down loaded some TI-82 programs related to algebra topics we had discussed. A few were able to find information on topics they were having difficulty with in class. Two students found activities related to their hobbies. A few indicated they were not sure how they would ever use the information they found, but they liked the activity anyway.

What is Learned?

This "case within a case" affirms Mr. Buck's skills and the value of multicultural math activities. It can be viewed as a "performance based demonstration" of Mr. Buck's ability to teach multicultural math. To the extent that this lesson reflects skills Mr. Buck has developed in the program, it gives one positive view of the program's effect.

It is evident from this lesson that Mr. Buck has both a clear sense of his class's diversity, as well as some strategies to address diversity. He is effective at "transmitting knowledge" using technology. The web sites provide math information that integrates with the life histories and cultural resources of his students, as poignantly evidenced by the student who wanted to introduce her family to the *Mathematicians of the African Diaspora.* Mr. Buck also effectively addresses socio-cultural dimensions of learning in his mathematics class. He directs students to Internet examples, data, and information representing a variety of cultures and groups. He fosters activities that provide opportunities for success to second language learners, in his "impromptu demonstrations" of how pencil and paper algorithms for long division are taught differently in different countries. Teaching to students' individual needs by connecting content and methods to students' knowledge and the real world, Mr. Buck places students at the center of the teaching and learning process. He portrays mathematics as belonging to everyone and empowers students with choices for investigation to match their interests (e.g., hobbies).

Mr. Buck asked his students for their reactions to the day's lesson, implying his commitment to refine his methods to meet their needs. His students show overall positive response to the lesson and make connections between their class learning and home, Internet, and hobbies. The lesson demonstrates an "additive" approach to multicultural math, and while it is not based on a specific content standard, it provides students many opportunities for problem solving and connections. Another strength of this lesson is that Mr. Buck wrote this case study to share. In that respect, he takes steps to increase infusion of multicultural math beyond his own classroom, a significant social action agenda. Mr. Buck entered the teacher preparation program after serving as an engineer and teacher in the Peace Corps in Lesotho, Southern Africa. He has taken advantage of all enrichment options offered in the program. Perhaps his skills exceed expectation. Still, his lesson gives reason for hope, and his work reflects well on his preparation program.

Conclusion

It is clear that multicultural math teaching, like all teaching in math, must promote thoughtful understanding of key mathematical ideas. This emphasis has grown as our experience with multicultural math has grown. In the early days of this initiative, project faculty focused on multicultural math as content inclusion (e.g., math that includes non-western history and modes of thought) or as math that focused on "real life" problems, thus connecting directly to diverse student experiences. Teacher candidates responded by producing an increasingly impressive array of lessons fitting that model. Still, early lessons sometimes showed little relationship to standards and tended to look like the "add-on" snippets in the columns of their teachers' guides. To facilitate student development of stronger lessons, we communicated a broadened definition of multicultural mathematics that focused more on thoughtful understanding in mathematics.

We also began to teach that multicultural math must be situated in classrooms with supportive and equitable communication patterns. The authors learned through observations that sometimes teacher candidates developed supportive classroom climates, and other times they didn't. It was a skill that needed to be taught. In terms of the definition provided, the socio-psychological climate of a math classroom became an important concern for the effective multicultural math teacher. This insight served as a catalyst for the development of the Equity Leadership Study Group which began in fall 1998. That group, in turn, has helped math teacher candidates to examine bias, develop intercultural communication skills, and learn about ways students' peers, families and communities impact their learning. Faculty collaboration and course reforms noted in this study promoted student teachers' use of multicultural math. The broadened definition of multicultural education, the implementation of the equity group, and excellent exemplars like Mr. Jeff Buck, promise to have an even greater impact.

Our journey has just begun— to effectively guide future teacher candidates to ever-higher levels of skill as multicultural math teachers.

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9 Teaching Physics in an Experiential Learning Studio Environment

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We work on problems throughout the lecture. . .
. . .direct tie-in of class and the laboratory. . .
I learned to look at problems differently, and analyze relationships.
Group study. . .made it significantly easier to learn difficult concepts.
—Comments from students in RMTEC physics classes

One of the major goals of the Rocky Mountain Teacher Education Collaborative (RMTEC) was to redesign first-year majors' courses in biology, chemistry, earth sciences, physics and mathematics for prospective teachers. The intent was to model effective inquiry-based, problem-oriented instructional strategies in content-specific courses that prospective teachers are required to take in their major area of study. This chapter will describe strategies that were implemented to modify Colorado State University's introductory physics courses as part of this initiative.

Overview

Introductory courses PH 121 and PH 122 are algebra-based with a laboratory component, and students who take them come from a wide variety of disciplines, with many from the biological sciences. The courses are recommended for pre-service science teachers, although some prospective physics and mathematics teachers take a calculus-based course. Because students who enroll in the PH 121/122 series come from very diverse backgrounds, often with little prior exposure to physics, these courses require the greatest degree of in-class explanation, demonstration, and motivation. They also are appropriate for modeling behaviors we wish future teachers to adopt — namely, an integrated lecture-laboratory approach based on understanding the material and problem solving, rather than a more traditional approach emphasizing rote memorization and application. This chapter will further describe some observations about teaching an integrated lecture, laboratory, and recitation class in an "Experiential Learning Studio" environment.

RMTEC Physics Strategies and Structure

Classes met for 2 1/2 hours, twice a week. The classroom was arranged with 24 desks clustered in groups of four, each forming an octagon with students seated on the inside. Students had their own space, yet there was an easy flow to interactions among members of each cluster and free flow for the instructor as well. Students took notes, solved in-class problems, performed laboratory experiments, and took exams at these desks, often acting cooperatively with their "cluster-mates." While the composition of clusters occasionally changed, in general they tended to be stable, with some groups continuing to operate more than two years after the class ended, and even maintaining contact after some members left campus. A good deal of camaraderie resulted from this use of cooperative learning, which promoted teamwork and information sharing. Most class sessions consisted of a variety of activities, including a mixture of problem-solving, demonstrations, and questions about homework from which further in-class questions developed— some emanating from students, many from the instructor. It was common to have a series of questions posed, escalating in difficulty and depth of understanding.

As the instructor, I was not at all reluctant to make an occasional class quite intense. During these sessions, attention was highly focused and students gained a great deal from the concentrated emphasis on concepts and immediate application to practical problems they were asked to comment on and solve.

Student Perspectives

The following are some comments from students on the RMTEC format:

I get to explain concepts to my classmates.

. . .direct tie-in of class and the laboratory. . .

We work on problems throughout the lecture. . .

Concepts, concepts, concepts!. . .In-depth learning was achieved.

I learned to look at problems differently, and analyze relationships.

Group study. . .made it significantly easier to learn difficult concepts.

From these remarks, we can see the importance of addressing the kinesthetic component of learning for those students who have had less experience than others. The more closely students can tie experience to concepts or theory, the greater their understanding of the subject matter. Importantly, this models the in-class behavior we wish pre-service science teachers to adopt for their core teaching. Facilitating this in a cooperative and participatory environment brings us closer to approaching true facilitation of learning. Student response was overwhelmingly positive to the RMTEC initiatives. Over 80 percent of the class thought that having enough class time to answer questions was "very-to-extremely" helpful, and 95 percent also agreed that the course was intellectually challenging.

Assessment of Learning

The value of utilizing new strategies and methods, however, is measured by how well students learn. The first exam given to the initial RMTEC class of 23 students was identical to the one given to the large, traditional lecture section of 485 students. RMTEC section grades averaged 60 percent, compared with the large section's 55 percent. These results were gratifying, since they indicated the populations were close to equivalent. On the next test, we decided to go to a nontraditional method of assessment, rather than using the multiple-choice method that was used for the first examination. However, we did include two questions on the second examination for the RMTEC class that were used by the traditional section. The traditional section averaged 82 percent and 62 percent, compared with the RMTEC section's average of 96 percent for the two questions.

We concluded that the conceptual emphasis used in the RMTEC class did not pose a barrier to solving "normal" types of questions. During the course of the year we could see C- and even D+ students performing at a C+ and B- level. Students attributed some of their increased understanding to doing "hands-on" work as they were exploring and discussing concepts — to actually seeing and knowing physics. We saw each cluster sharing and interchanging responsibilities. Gratifyingly, female students actively participated, and often assumed leadership roles. The structure also allowed team members to respond quickly to errors.

Use of Teachers-in-Residence

Another RMTEC strategy was the use of Teachers-in-Residence (TIRs). Each year RMTEC selects master teachers from the public schools to serve as Teachers-in-Residence on each of the primary RMTEC campuses. These individuals bring experience teaching one of the subject matter areas of RMTEC, and have a grounding in standards and assessments required in public schools today. In most instances, they are on leave or sabbatical from a local school district.

Teachers-in-Residence were usually paired with mathematics or science faculty members. This arrangement brought an understanding of what currently is taking place within secondary schools, and a depth of knowledge otherwise unobtainable by those viewing secondary education from the outside, or not directly involved with public education. Coming with this background, TIRs are invaluable resources for college and university faculty striving to improve the preparation of pre-service teachers in education, mathematics, and science classrooms while enriching undergraduate classrooms with new and varied instructional methodologies. In addition, Teachers-in-Residence witness first-hand the struggles of faculty in higher education to reform the educational experiences of future teachers while introducing potentially new and different subject matter to students.

Two Teachers-in-Residence were involved in the RMTEC physics classes, one each during the 1996/97 and 1997/98 academic years. Their presence was invaluable. They were able to communicate directly to me about the backgrounds, knowledge base, and likely responses of students coming from high school. For their part, they gained insight into what we as a university community expect from students in our classes. The two Teachers-in-Residence differed in their contributions to the class, and in what they took away. One played a very active and direct role in teaching the class and brought in many materials to use, such as videos, which were not standard fare at Colorado State University. The other was less active directly, but devised 50 or more activities that could be used in both high school and university settings. Both appreciated the professional development work with physics faculty members while increasing their depth of understanding and updating their content knowledge. They both helped me understand how the K-12 State Standards are applicable to physics courses, and at the same time they saw the latest content and areas of emphasis at the university level. They were glad to develop new relationships and alliances with university personnel.

In summary, the two Teachers-in-Residence who were involved with RMTEC physics classes returned to the public school system with a greater sense of satisfaction and dedication to the development of relationships between K-12 faculty and higher education. Upon returning to the public school system, they provided professional development training to other teachers on new content updates based on the research they observed while working with higher education faculty, as well as ideas on how to better link K-12 courses to introductory physics courses at the university. They also serve as cooperating teachers for RMTEC student teachers, thus promoting the ideals of the reformed classroom. They leave a legacy of improved instructional strategies within undergraduate classrooms, and continue to provide a network at the local level for K-16 reform.

These Teachers-in-Residence responded to the questions, *Do you feel the RMTEC courses will contribute to the future success of mathematics and/or science teachers? Why?* as follows:

Yes, the education courses seem outstanding preparation for pre-service teachers, both in the sense that they are taught via methods they will be expected to use when they are teachers as well as through the extensive practicum experiences required in different schools at different levels.

The physics class was a far more user-friendly way for students to learn their physics and I think many students walked away with the confidence that they knew how to approach a conceptual problem, whether they felt they could solve it mathematically or not. The response of gratitude from the students for taking the time to make it all make sense was universally expressed, individually to the professor, teacher-in-residence, and teaching assistant alike.

Faculty Perspective

There is a component to teaching experiments that is often discounted — the response of the teacher. I can honestly say that the RMTEC experience has been one of the most rewarding I have had in a classroom. A closeness to the students developed that is nearly impossible to achieve in other ways, especially in traditional science courses. At the same time, a higher expenditure of energy was required for teaching the integrated course because of the need for more extensive planning, and the more concentrated time spent in the class.

Future Planning

In conjunction with my department chair, we are planning to introduce a modified version of the RMTEC technique appropriate for large sections. One suggestion students had for the course structure was to schedule shorter periods. We can achieve this by having two 2-hour sessions of integrated laboratory and recitation, and two separate hours of lecture. This represents a compromise between the traditional and the RMTEC techniques described in this chapter, but it will be more compatible with the practices and capabilities of more traditionally-oriented faculty, thereby making it easier for them to participate. Time calculations indicate that we will spend slightly more time with the integrated lecture laboratory than we would using traditional methods, but projections are reasonable enough to make an attempt to implement a new system feasible. Greater attention to the preparation of teaching assistants will be required.

RMTEC Techniques Used with Honors Students

During the 1998/99 academic year, the RMTEC approach was used with a group of Honors students. The response was quite different from what was anticipated. Most of these bright students were quiet in class; they did not quickly respond to questions asked in class. They listened carefully, and scores on exams indicated they were taking in the information, but they were reluctant to volunteer answers and participate. It took them a long time to loosen up and work smoothly with others. This experience has made me think again about the pedagogy and content knowledge needed by students we wish to recruit as science teachers.

For example, most Honors students are very field-independent, which I believe makes them less effective in relating to others — in this case, their students. They also are not likely to be adept initially at teaching others in an increasingly cooperative learning environment. They are more likely to resort to formal responses in answering questions, rather than relying on experiential methods. Since we must build on what students already know, we need teachers who can understand their students' level of preparedness — that is, teachers who have the ability to blend cognitive and affective skills, which I describe as field-dependent persons.

Some of the above may be tempered by the fact that PH 121 and PH 122 are primarily populated by juniors, while the Honors classes, on average, are populated by freshmen and sophomores. Perhaps some of the difference in students' response can be attributed to maturity. But discussions with other Honors Program faculty, including the head of the program, lead me to believe that my conclusions are fundamentally correct. We may prepare more successful teachers by directing our attention toward encouraging empathetically oriented students and ensuring that their educations in science content are more solidly grounded in conceptual understanding of both content and pedagogy. This is best done in a RMTEC learning format so that students have a deeper, hands-on, conceptual understanding of the material they are to teach. We can provide this by stressing fundamentals and depth of comprehension, and planning carefully so that covering the totality of course material does not take precedence over students' cognitive growth.

Final Thoughts

We face a dichotomous circumstance in recruiting and educating prospective teachers. This is especially true for the sciences, where formal reasoning is required for understanding many concepts, and a field-independent personality is almost a prerequisite for doing well. On the other hand, a field-dependent person will be best able to cooperate in learning, and best able to relate to student needs. Our challenge is to promote both of these valuable qualities in our future teachers, and RMTEC has helped to develop strategies for meeting this challenge.

10 Chemistry Reform Takes Root in University Setting

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Which of the following scenarios is more attractive?

(1) You arrive for chemistry class and listen and watch an instructor work problems about gas laws for fifty minutes.

(2) You arrive for class and you and a few other classmates analyze data about the relationship between pressure and volume and develop the gas laws based on data.

Unfortunately, the first scenario is the one most students who have had general chemistry remember. At the University of Northern Colorado (UNC), the Chemistry Department has attempted to move toward the second scenario. The progress of this change is described in this chapter.

Rocky Mountain Teacher Education Collaborative (RMTEC) chemistry reform at UNC proceeded in three distinct directions in an effort to reach the second scenario. The general chemistry course was the target for two revision efforts. An upper division chemistry course taken by all chemistry-teacher education majors was the focus of the third effort. Each of these efforts has been or is being evaluated by faculty and chemical education graduate students. The following description is divided into three sections – one for each reform effort.

Cooperative Learning in the General Chemistry Classroom

This reform targeted the delivery method used by faculty in the general chemistry course. A set of cooperative learning activities (Geiger, Straushein, & Jones, 1997) was developed to facilitate the use of cooperative learning in the classroom. Goals of cooperative learning for general chemistry classes at UNC include: increasing student achievement, teaching students to become active learners who assume a greater responsibility for their own learning; teaching students group processing and social skills; encouraging interactions between students of diverse backgrounds; and building a sense of classroom community.

To evaluate the effectiveness of course revisions, a detailed statistical study was conducted with respect to the above goals (Geiger et.al., 1998). One faculty member taught two sections of first semester general chemistry — one without cooperative learning groups, and one with cooperative learning activities. Achievement was measured by comparing scores on in-class exams and final course grades. An independent observer measured student interaction and involvement. The observer noted who asked questions, the types of questions they asked, and who answered the instructor's questions.

Results suggest several conclusions. First, the use of cooperative groups does not increase chemistry achievement, as measured by tests; however, the use of cooperative groups does change the distribution of grades. This suggests that for some students, the use of cooperative groups influences their achievement. Smith, Hinckley, and Volt (1991) found that lower achieving students in the cooperative group setting scored significantly higher than their counterparts in the traditional laboratory setting. It also appears possible that female students' achievement is improved in the cooperative learning environment. Second, cooperative group settings increase the voice of females during class discussions. Not only is the involvement of female students increased in this setting, but the increase in the number of higher order questions suggests that they are actively involved in learning. Third, cooperative groups increase the percentage of higher level questions from both male and female students. Classroom observations suggest that both male and female students took a more active role in the cooperative group classroom than in the lecture setting. Even without statistical gains in achievement, cooperative groups offer advantages to students when compared with lecture sections. Reports of similar findings support this assertion. (Dougherty, R.C., Bowen, C.T., Berger, W.R., Mellon, E.K., & Pulliam, E., 1995; Cooper, 1995)

Introduction of Inquiry Into the General Chemistry Laboratory

A second focus was to introduce guided inquiry experiences into the general chemistry laboratory. This reform involved rewriting the freshman chemistry lab manual. Each experiment was evaluated for the use of inquiry. Experiments were rewritten or modified so that students are expected to develop procedures of their own. Students are given a task, for example, to determine the energy change during the melting of ice. They identify experimental variables and determine how to measure them. Students then perform the experiment and analyze the data. Over the past 2 years, the second semester course has been further modified to include a larger inquiry project. During this project, students select and design an investigation on their own. The instructor acts as a supervisor or collaborator. Students submit a research idea and proposal to the instructor who evaluates the proposal and provides feedback to the student. The student then performs the experiment and analyzes the results. Students are given the opportunity to repeat the experiment to improve the results or incorporate any changes they feel are necessary. This inquiry project is currently being evaluated. Initial results (Krystyniak & Langdon, 1998) indicate that students enjoy the experience. The development of this inquiry experiment is an example of the institutionalization of the RMTEC model. Graduate students involved in this project were not at UNC during the RMTEC revisions.

Guided Reading Approach to *Survey of Physical Chemistry* Course

The third reform effort involved the one-semester *Survey of Physical Chemistry* course. Students in this course are majoring in chemistry with an emphasis in one of the following areas: Pre-Health, Industrial Chemistry, and Secondary Education/Teaching.

Revisions focused on getting the students more actively involved in the course. The need for students to be active participants has been reviewed in Herron (1996). Our revisions were based heavily on the work of Zielinski (1994, 1995) and her use of guided readings. Specifically, our goals for the revision were as follows: maintain a rigorous survey of physical chemistry that will deepen students' understanding of physical chemistry; move from an instructor-centered environment to a student-centered learning environment; and have students assume responsibility for their learning.

Course delivery was redesigned to be based on the use of guided reading packets instead of lecture. These packets consist of questions and problems students answer while they read assignments from the text. Types of questions range from straightforward questions where the answer is found directly in the text, to more complex, higher order questions that require students to stretch their understanding of the material.

Students are given guided reading materials and a daily assignment. They are expected to come to class with the guided reading assignment completed. Class time is spent in one of three ways. The majority of class time is spent in small-group discussion of student answers to the assigned questions and problems from their guided reading packet. One student is chosen to be the discussion leader and the instructors float around the class, dropping in on different groups to monitor their progress and resolve any unanswered questions. Time also is spent in student presentations of their solutions to assigned problems. Finally, lectures have not been totally replaced; instead, mini-lectures of 5-15 minutes are periodically presented on more complex or supplementary material.

Use of guided reading packets has been evaluated (Pentecost & James, 1999), with goals for the revision in mind. To determine if the classroom environment had changed from instructor-centered to student-centered, classroom observations by an independent observer were done. Student interviews were conducted to determine if the responsibility for learning had been shifted to the students. Finally, course evaluation surveys developed by RMTEC were used to evaluate students' perceptions of the learning environment.

Results indicate that the guided reading packet approach can create a student-centered classroom environment. In this environment, students realize that the responsibility for learning has shifted to them. This approach also increases the frequency of the students' use of the textbook. Results suggest that while students are receptive to this type of teaching, it would be most effective if students were exposed to student-centered learning environments earlier in their college careers. It seems that for some students, the sudden shift in focus from instructor to student was not pleasant. As it was, students seemed to appreciate the effort to improve the instruction and found the approach helpful.

Conclusion

Chemistry reform at the UNC has taken root. Other instructors have begun using cooperative groups in their courses to some extent. The inquiry laboratory experience is becoming institutionalized so that it remains a vital part of the general chemistry laboratory program. The physical chemistry course is being taught for the fourth year using the guided reading approach. Students taking chemistry at UNC are more likely to find chemistry an active and inviting subject rather than a passive study of isolated facts.

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